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RANDOM SAMPLING FOR EXTRAPOLATED
DEDUCTIONS IN NAVY MAINTENANCE
SERVICE CONTRACTS

by

Robert Anthony Maholchic

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Random Sampling for Extrapolated Deductions in Navy Maintenance Service Contracts

by

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ABSTRACT

This thesis examines the use of random sampling as a basis for taking extrapolated deductions in the payment of Navy maintenance service contracts. Motivated by increasing inspection requirements, NAVFAC has authorized limited use of this quality assurance tool. The experience of two activities which implemented extrapolated deductions in their family housing maintenance contracts is the focus of this study. Methods employed are evaluated along with an analysis of payment history, contractor performance and inspection requirements. The statistical basis used in the field tests along with an alternate proposal is analyzed. Various issues are identified which should be addressed before general guidance is promulgated. Major recommendations deal with sample adjustment, computer support, inspection methods and the need for oversight.

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I. INTRODUCTION

A. BACKGROUND

Random Sampling for Extrapolated Deductions (RSED) involves making an inference concerning a population based on a simple random sample. The results of that sample are then used as a basis for equitable payment across the entire contracted service. As a simple example, suppose that a sample inspection of services revealed 10% not performed. The contracting officer would then estimate that 10% of all services were not performed, and reduce the contract price by 10%. While payment deductions for observed poor performance or nonperformance by service contractors is standard practice, the extrapolation of deductions based on random sampling to the general population is currently prohibited by NAVFAC regulation. This policy has been under review in recent years.

Interest in this technique is a result of the increasing role that service contracts play in accomplishing the base maintenance function and the subsequent strain placed on the inspection force. As part of a move toward formulating Navy policy, two activities were granted authority to use extrapolated deductions in their Family Housing Maintenance Contracts.

B. OBJECTIVE

The objective of this research is to evaluate the field use of random sampling for extrapolated deductions in Navy maintenance service contracts. This is being done to identify issues which should be addressed before general authority is granted and guidance promulgated. In addition, proposed NAVFAC statistical methodology is evaluated in light of information obtained in the course of this study.

C. SCOPE AND ASSUMPTIONS

This study focuses on the procedures used to implement the field testing of random sampling for extrapolated deductions in Navy maintenance service contracts. Air Force use of this contracting technique is addressed to provide a background and contrast to the NAVFAC effort. Experiences of other service contracting organizations with extrapolating deductions either within or outside the Federal Government was not pursued. It is assumed that the reader is familiar with the concept of simple random sampling.

D. RESEARCH METHODOLOGY

A literature search was conducted to review regulations, reports, industrial literature, and policy guidance applicable to statistical quality assurance and service contracting. Contact documentation and history was obtained

from the following organizations involved in the initial use of extrapolating deductions:

1. Public Works Center, San Francisco, Ca; and
2. Public Works Center, Great Lakes, Il.

Additionally, interviews were conducted either in person or by telephone at the following organizations:

1. Public Works Center, San Francisco, Ca;
2. Public Works Center, Great Lakes, Il;
3. Western Division, Naval Facilities Engineering Command, San Bruno, Ca;
4. Public Works Center, San Diego, Ca;
5. Public Works Department, Naval Postgraduate School, Monterey, Ca;
6. Public Works Department, Marine Corps Air Station, El Toro, Ca;
7. Vandenburg Air Force Base, Lompoc, Ca.

E. THESIS ORGANIZATION

This chapter identified the current status of NAVFAC regarding the extrapolation of deductions in service contracting and presents the objectives and methodologies of this study. Chapter II puts the study into perspective with a discussion of the maintenance service contracting environment. Chapter III traces the historical development of statistical quality assurance techniques and their application to service contracting. Chapter IV examines random sampling, NAVFAC policy concerning RSED, and two statistical approaches that have received consideration as a basis for

extrapolating deductions in NAVFAC service contracts. Chapter V presents findings and conclusions resulting from an evaluation of two activities implementation of extrapolated deductions in their family housing maintenance contracts. Finally, Chapter VI lists recommendations for the general use of extrapolating deductions and makes suggestions for future research.

II. MAINTENANCE SERVICE CONTRACTING ENVIRONMENT

A. BACKGROUND

A Maintenance Service Contract (MSC), commonly referred to as simply a service contract, calls for a contractor's time and effort rather than a finished product. Service contracts are funded by the organization having budgeted responsibility for the services acquired. Examples of service contracts include refuse collection, guard services, grounds maintenance, pest control, and family housing maintenance. A MSC is normally entered into for a one year period with an option to extend for two additional one year periods. However, extensions to the contract cannot exceed the fifth anniversary of contract award. [Ref. 1]

While not a critical distinction for purposes of this paper, a MSC is one category of a Facility Support Contract. The other category is a Maintenance Construction Contract. Due to the nonrepetitive nature of construction and the higher degree of importance associated with each unit of work, they are not normally amenable to statistical quality assurance and will not be a focus of this study.

Facility Support Contracts are designed to accomplish the maintenance and repair of real property facilities. They can best be thought of as an extension of the base public works force, and in fact replace the in-house forces

where a decision has been made to contract out a function previously performed by Public Works.

Service contracts are almost exclusively of the fixed price type. It is the belief of NAVFAC that fixed price contracts force contractors to perform efficiently. Where uncertainty of workload precludes a firm fixed price, Indefinite Quantity contracts are awarded on the basis of firm unit prices for an estimated workload. This study encountered the extrapolation of deductions being applied only to firm fixed price contracts, however the technique is also applicable to firm unit prices. [Ref. 1]

B. TREND TOWARDS SERVICE CONTRACTING

Service contracting in the public sector gained attention in 1954 when, in his first budget message to Congress, President Eisenhower said: [Ref. 2]

> This budget marks the beginning of a movement to shift to . . . private enterprise Federal activities which can be more efficiently carried on that way.

This was followed by Bureau of the Budget Bulletin 55-4 which implemented the stated policy as follows: [Ref. 3]

> It is the general policy of the administration that the Federal Government will not start or carry on any commercial activity to provide a service or product for its own use if such service or product can be produced from private enterprise through ordinary business channels. Exceptions to this policy shall be made by the head of the agency only where it is clearly demonstrated in each case that it is not in the public interest to procure such products or services from private enterprise.

Today's policy comes from OMB Circular A-76, issued in 1966 and further revised in 1967, 1979 and 1983. It

basically states that whenever a commercial activity is Federally operated, the cost of operation should be compared to the cost of contracting to determine who should do the work. A commercial activity (CA) is defined as a product or service obtainable from a commercial source. [Ref. 4]

Although it has been federal policy to contract out commercial functions since the 1950s, the program was largely ignored until the 1979 revision of A-76 [Ref. 5]. A key element of that version required government forces to submit a "firm bid" based on a clear Statement of Work (SOW). Contractors would also bid on the requirements contained in the SOW. Thus the open market would determine the contracting decision. Award would be to the lowest responsible bidder if under the government estimate by 10%. To ensure that the government estimate was properly prepared, it was subject to approval by the Naval Audit Service [Ref. 6].

Thus, the fact that DODI 4100.33 required a complete review of all CA functions and a compliance system was in place set the stage for a number of functions formally performed by Public Works to be contracted out.

Data compiled in January 1982 showed that 60% of all functions reviewed shifted to contract, at an overall cost savings of 19%. Of all NAVFAC functions studied, the areas of transportation, grounds maintenance, building maintenance, and janitorial service accounted for 82% of the total

[Ref. 7]. The next few years will undoubtedly see conversions occur at an ever increasing rate as the great majority of reviews are completed.

C. PERFORMANCE

Service contracts, while not directly mission related, are usually of great concern to the activity commanding officer. Visible lack of performance reflects directly on his ability to effectively maintain the shore establishment entrusted to his care. The result is acute command interest in performance, an interest which is reflected throughout the contracting organization.

Acceptable performance in service contracts is often difficult to achieve. While a consensus of opinion did not emerge during personal interviews, frequently cited reasons included a lack of inspector resources, inadequate specifications, and a lack of enforcement techniques to motivate the contractor.

D. QUALITY ASSURANCE

Quality Assurance (QA) is the procedure by which the government verifies that it is receiving the services for which it contracted and paid for. Quality Assurance Evaluators (QAE) are responsible to the Service Contract Manager (SCM) for actual monitoring of contractor performance. The QA program is contained in the QA Plan. it details how the QAE will monitor all aspects of a

contractor's performance, although it is not part of the actual contract.

Several surveillance methods may be used as part of the QA Plan. Those selected are based on the unique considerations of an activity. Techniques currently in use are: [Ref. 8]

a) One Hundred Percent Inspection--Appropriate for infrequently performed services or those of great importance, it is expensive and time consuming.

b) Planned Sampling--Designed to inspect some part of the contract requirement. It cannot be used to make an overall judgment concerning contract performance, but is useful where performance in a particular area or location is of interest.

c) Unscheduled Inspection--An impromptu check.

d) Validated Complaints--Originate with the customer. The method is successful to the extent that customers are aware of and can distinguish good performance. While not recommended as a stand alone procedure, it can be used to make payment deductions and require rework.

e) Random Sampling--A statistically based procedure which attempts to incorporate the best features of 100% inspection and planned sampling. By inspecting a sample representative of the entire population, it allows a judgment to be made about overall performance with a reduced level of inspector resources. A properly constructed random sample may also be the basis for extrapolating deductions. However, the extrapolation of deductions is currently not allowed by NAVFAC regulation and is the focus of this study.

E. ENFORCING PERFORMANCE

If the government accepts anything less than 100% of contract bid requirements, the contracting officer must take some appropriate action. Not to do so could indicate that

the government has overstated its requirements resulting in an illegal contract.

Other than the routine identification of contractor deficiencies, negative motivators form the basis of NAVFAC approved techniques to enforce performance. Contract actions other than payment reduction are all designed to threaten and support eventual default for failure to perform. The effectiveness of these techniques are questionable because of the difficulty in sustaining termination of a borderline contractor. In addition, the prospect of extended litigation and interruption in services must be considered. Conversations with contracting officers indicate that "living" with less than acceptable performance until contract expiration is the best of a bad situation. It is reasonable to assume that a savvy contractor is aware of the contracting officer's dilemma.

The most effective performance motivator currently permitted is the withholding of payment for unsatisfactorily performed services. Withholding payment assumes a strong profit motive on the part of a capable contractor, a "fair" contract under which reasonable profits are possible, and a schedule of deductions which results in reduced profits when exercised. Other possible contractor motivations such as growth or maintenance of the workforce do not appear valid in service contracting. Contractors generally do not staff for a job until contract award, and a ready supply of

unskilled or semiskilled laborers makes adjustment of the workforce an easy thing to do.

Current NAVFAC regulations allow deductions for work not acceptably performed, unless the contractor is given the opportunity to re-perform the work and does so satisfactorily. If feasible, rework is preferable to deductions because of the emphasis on performance. When taken, deductions are in accordance with individual bid items if an Indefinite Quantity contract, or an agreed-upon schedule of deductions for Firm Fixed Price contracts. However, this contract action is limited by the fact that appeals boards and courts uniformly hold "penalty" provisions unenforceable. Section 9-302.1 of the Navy Contracting Manual applies: [Ref. 1]

> No contract may provide for penalties for non-performance, as such are legally unenforceable. However, a contract may provide for liquidated damages, which is an advance agreement between parties to a contract as the damages one party will suffer if the other fails to perform . . . Note that if a contractor does not perform work, it would be improper to withhold payment for that work AND also charge him the full cost of having the work done by others, for that would result in the Navy having work done at the expense of others.

Liquidated damages of 10% are assessed whether or not the work is subsequently performed by the contractor to compensate the government for increased administrative costs. Where government forces re-perform the work, a 20% liquidated damage charge is levied along with the full cost of the government effort. [Ref. 1]

Current NAVFAC regulations allow deductions for observed defects only. The extrapolation of deductions based on random sampling is prohibited [Ref. 8]. This policy resulted from the lack of an acceptable statistical technique and questions as to the legality of extrapolated deductions. However, NAVFAC has recognized the potential of extrapolating deductions to further motivate the contractor, or at least to better match payment for services received. Therefore they have initiated efforts in recent years to define a methodology under which extrapolation might be authorized for general use. In support of this effort, NAVFAC has authorized trial tests of extrapolating deductions in family housing maintenance contracts at PWC San Francisco and PWC Great Lakes.

III. HISTORICAL OVERVIEW OF STATISTICAL QUALITY CONTROL

A. EARLY EVOLUTION

Since man began to manufacture and produce products, there has been concern over quality of output. As far back as the Middle Ages, the medieval guilds insisted on apprenticeships and required that those seeking to become master craftsmen offer evidence of their ability. Such rules were in part a form of quality control. In more modern times, factory inspection and research, activities of professional societies, and various regulations have sought for years to assure a quality of output. Quality control has thus had a long history.

On the other hand, statistical quality control is relatively new. The science of statistics itself goes back only about 300 years. The theory of probability originated in 1654 when Pascal, a French philosopher and mathematician, teamed up with Pierre Fermat to develop the new science. Early applications were made in astronomy and physics, but it was not until the 1920's that statistical theory began to be applied effectively to quality control. It should be remembered though, that even before the 1920's, industry was learning to do things more scientifically. Techniques such as the GANTT chart, under principles developed by Taylor,

Gilbreth and others were a part of the movement called "scientific management."

Walter Shewhart, of the Bell Telephone Laboratories, was among the first to apply statistical methods to the problem of quality control [Ref. 1]. Two other Bell System men, H.F. Dodge and H.G. Romig, took the leadership in developing the application of statistical theory to sampling inspection. The culmination of their work being the now well-known Dodge-Romig Sampling Inspection Tables. An immense amount of work went into the preparation of these tables, for at that time hand calculators were the only available aid to speedy calculations. These tables were published in 1941 [Ref. 2]. The work of Shewart, Dodge, and Romig constitutes much of what today comprises the theory of statistical quality control.

When this new inspection plan was proposed there were many skeptics. Therefore, in the initial trials, after performing sampling inspection, every lot was then inspected 100% to check conformity. The checks showed that sampling did give good results and with much less time and money used for inspection. After its initial application in the central offices of Western Electric Company, the new procedures were tried in the Hawthorne manufacturing plant in Chicago, and proved a big success.

The rate of adoption of these newer methods were slow in the United States. Professor Freeman, who was promoting

statistical quality control at Massachusetts Institute of Technology, ascribed this sluggish response of the early years to: (1) the conviction of American production engineers that their principal function was to improve quality control through advances in technology, (2) a prevailing attitude that the laws of chance had no place in a scientific field, and (3) the scarcity of adequately trained industrial statisticians. In 1937, probably not more than a dozen single enterprises in American mass-production industry had introduced the new techniques into their ordinary operations. [Ref. 3]

B. INFLUENCE OF WORLD WAR II

World War II overcame the initial coolness of American industry toward statistical quality control. The armed services began to enter the market as large consumers of American output and, as such, had an increasing influence on quality standards. A group of engineers from Bell Telephone were brought to Washington to develop a sampling inspection program for Army Ordnance. This step was made necessary by the bottlenecks occurring at inspection stations during full scale production.

The group from Bell faced a sampling problem of unprecedented size. It was necessary that all vendors be treated fairly; it was necessary to get enormous quantities of ordnance material quickly; and it was necessary that arms and ammunition be reliable and safe. The "acceptable quality

control" system that was developed encompassed the concept of protecting the consumer from getting unacceptably defective material, and encouraging the producer in the use of process quality control. This was done by varying the quantity and severity of acceptance inspections in direct relation to the importance of the characteristics inspected, and in inverse relation to the quality level indicated by those inspections [REf. 4]. The same men also carried out an extensive training program to acquaint government personnel with the new procedures and tables. Many terms used extensively today, most notably "producers risk" and "consumers risk," had their origins in this original effort.

Wartime research in statistical quality control was carried out primarily by the Statistical Research Group, Columbia University, Applied Mathematics Panel, Office of Scientific Research and Development. This research group was organized in July 1942, and continued in existence until September 1945. Members of the staff were drawn from universities around the country. It advised and assisted the Army and Navy on statistical aspects of problems arising in their activities. Included in its contributions to statistical quality control was the preparation of the Navy manual on sampling inspection by attributes [REf. 5]. Inspection by attributes requires that the inspected item be categorized either as totally acceptable or not acceptable.

Professor A. Wald, also of the Statistical Research Group, developed the idea of sequential sampling. In sequential sampling, the sample size is not determined in advance. The sequential procedure is to inspect one item at a time. The inspection is continued until enough cumulative evidence has been gathered to either accept or reject a lot. A pre-assigned risk of making incorrect decisions controls the ultimate same sample size. This procedure allows very good lots to be accepted quickly and bad lots to be rejected quickly. It is only with lots of doubtful quality that extensive sampling is required. This analysis was deemed so important by the U.S. Government that it withheld publication of Wald's original paper until June 1945. [Ref. 5]

C. MILITARY STANDARDS (MIL-STD-105)

1. Development

In the post war period there were two systems of sampling plans and tables, Army tables and Navy tables. The procedures and tables were alike in general plan and structure but differed in a number of respects. In 1949, a basic Military Standard, MIL-STD-105, was developed using material from both service tables. Military Standard 105D, the current version, is the outcome of a study by an American-British-Canadian working group that sought to derive a common standard for the three countries. MIL-STD-105D was issued by the U.S. Government in 1963. In 1971, it was adopted by the American National Standards Institute as ANSI

Z1.4 and in 1973, it was adopted by the International Organization for Standardization as ISO/DIS-2859. [Ref. 6]

2. Acceptance Sampling

Acceptance sampling is the method of evaluating a group of units, drawn from a production lot, in order to determine the acceptability of the whole lot. It has been widely accepted as the preferred method of acceptance control. MIL-STD-105D provides tables which facilitate the implementation of an Acceptance Sampling by Attributes plan. The focus of the plan is an acceptable quality level (AQL). An AQL represents that quality level which, for purposes of sampling inspection, can be considered satisfactory as a process average. [Ref. 15]

In addition to an initial decision on an AQL, it is also necessary in applying MIL-STD-105D to decide on an "inspection level." This determines the relationship between the lot size and the required sample size. Three inspection levels are provided for general use with guidance for switching between them.

For a particular sample size and AQL, the tables will specify a reject number. When the number of defects in a sample is equal to or greater than the reject number, the entire lot is judged to be unacceptable. The sample size, reject number, and AQL define an "operating characteristic" curve for a particular plan. This curve depicts the relationship between the actual defect rate submitted for

inspection and the corresponding probability of acceptance of such lots by the sampling plan. It is based on the binomial distribution.

The nature of acceptance sampling is explained by Siegmund Halpern: [Ref. 15]

> Inasmuch as only a portion of the whole lot is inspected, there is always a risk that the quality of the sample will not reflect the quality of the lot. As a result, production lots may, at times, undeservably be rejected and faulty lots accepted. The former will be of interest to the producer. He wants to minimize the risk of having good lots rejected. This risk is identified as the producer's risk. The risk of accepting bad lots in a sampling scheme is, of course, the primary concern of the consumer. This risk is called consumer's risk. The method by which both the producer's risk and the consumer's risk are quantified statistically is by constructing an operating characteristic curve.

Acheson Duncan also comments: [Ref. 9]

> It is to be emphasized that the purpose of acceptance sampling is to determine a course of action, not to estimate lot quality. Acceptance sampling specifies procedures that, if applied to a series of lots, will give a specified risk of accepting lots of a given quality.

Appendix A illustrates how the sampling plans contained in MIL-STD-105D are used. A typical operating characteristic curve is also presented.

3. <u>Application to Air Force Service Contracting</u>

Random sampling as a quality assurance tool for monitoring contractor services was introduced to the military by the Air Force in 1979 with AFR 400-28. MIL-STD-105D provided the basis for the random sampling procedures contained in the regulation. [Ref. 16]

Originally designed to determine the acceptance or rejection of manufactured lots, MIL-STD-105D was easily adapted to the service contracting environment. Specific instances of work could be judged "defective" or acceptable, as required in attribute sampling, the same as a manufactured part. Lot size was normally determined by the number of services provided in a month, which corresponded to a pay period. A major difference between the use of acceptance sampling for manufactured items and evaluating service contract performance is that a "lot" of services could not be totally rejected if found unacceptable, since it had already occurred. Therefore, contract actions based on the results of acceptance sampling must recognize that some satisfactory work has taken place for which the contractor is due payment.

AFR 400-28 contains tables derived from MIL-STD-105D that show acceptance and rejection numbers corresponding to specified acceptable quality levels and sample sizes. The acceptance number is the maximum number of defects allowed before a sample is considered unsatisfactory. When the number of defects in the sample exceeds the acceptance number, contractor performance is deemed unsatisfactory and contract payments can be reduced for the service provided during the sample period.

Allowable AQLs are limited to those which appear in MIL-STD-105D. AFR 400-28 calls for the establishment of

reasonable AQLs as part of the original CA solicitation. Thus contractors bid on performance requirements of less than 100% for various services. Contractors are also provided with the activities QA plan as an enclosure to CA solicitations. This is done to inform prospective bidders as to how the contract will be monitored and to help them set up their own quality control program. It is not, however, a part of the contract.

The extrapolation of deductions is a key feature of AFR 400-28. When the random sampling method of surveillance is used and the service is rejected, contractor payments may be reduced in the same proportion for the entire lot as the percentage of defects found in the sample. For example, if a rejected sample disclosed that 15% of an inspected service was defective, contract payments for the service may be reduced by 15%. However if the number of defects found do not equal or exceed the reject number, the services are judged satisfactory and no deductions are taken.

Numerous problems have been experienced at the activity level in implementing AFR 400-28. An audit conducted by the Air Force Audit Agency in 1985 to evaluate quality assurance of base-level service contracts reported the following findings: [Ref. 17]

a) for seven of twenty contracts reviewed, QAEs made errors in the use of random number tables;

b) for fifteen of twenty contracts reviewed. QAEs did not correctly use random sampling techniques due to the complexity of AFR 400-28;

c) for ten of twenty contracts reviewed. QAEs did not properly apply accept/reject numbers due to the complexity of the AFR 400-28 acceptance tables; and

d) sampling plans were not an effective means of determining contractor's performance as the plans used frequently required the acceptance of services even though the percentage of defects occurring in the sample was approximately twice the defect rate permitted in the contract.

The Air Force is now investigating a simplified random sampling process based on Indifference Quality Levels. In such a plan, the government and the contractor equally share in the probability of acceptance or rejection at a specified quality level [Ref. 17].

4. Navy Rejection of MIL-STD-105D

NAVFAC service contracts are written requiring 100% performance. Thus the Navy is more interested in a statistical methodology which will provide information as to actual contract performance rather than the accept/reject hypothesis testing of MIL-STD-105D.

A random sampling procedure was designed by NAVFAC in 1979 to determine the level of contractor performance. Published in the MO-327 [Ref. 8], which is the Navy equivalent of AFR 400-28, it was not intended to be a statistical basis for extrapolating deductions. The sampling plan contained in MO-327 made use of an AQL that was not releasable to the contractor. This AQL differed from the one used in MIL-STD-105D in that it was defined to be "tolerable" performance rather than acceptable.

The new contract surveillance technique was not widely used. Conversations with contract administrators indicated that this method of random sampling was hard to understand, difficult to administer, and provided questionable results upon which to base contract actions. Adding to that the fact that extrapolated deductions were not permitted, there remained little incentive for its use over the more understandable planned-sampling technique.

In 1982, NAVFAC determined that the extrapolation of deductions was appropriate as long as there was a degree of confidence that deductions made were reasonable and not construed as penalties. Their approach is studied in the following chapter.

IV. RANDOM SAMPLING FOR EXTRAPOLATED DEDUCTIONS

A. INTRODUCTION

Random Sampling for Extrapolated Deductions (RSED) involves making an inference concerning a population based on a simple random sample. The results of that sample are then used as a basis for equitable payment across the entire contracted service.

There are three reasons why the concept of extrapolating deductions is supported by NAVFAC at this time: (1) it is believed to provide extra motivation for the contractor through the potential of increased deductions, (2) extrapolation results in a better match of payment to services received, and (3) the ability to extrapolate deductions makes the use of random sampling more attractive as a quality assurance tool. Given the current service contracting environment, the ability to obtain acceptable evaluation of contractor performance with reduced levels of inspector resources would appear to be the predominant issue.

The application of extrapolated deductions must be based on a statistically valid random sample if a protest is to be upheld. Most activities have had no experience with random sampling and the guidance available is limited in value. The next section looks at the considerations involved in

employing random sampling in a service contracting environment.

B. RANDOM SAMPLING

1. Characteristics

A properly constructed random sample must ensure that every possible sample of a given size has an equal chance of being selected. Additionally, the process being inspected must be homogeneous and produce defects in a random manner. If this is not the case, a selection bias may result which causes the attributes of the sample to be different from the population. [Ref. 18]

This theoretical ideal, approachable in manufactured lots, cannot realistically be attained in service contracting. Some rooms are going to be harder to clean than others. A bus service will be more likely to lag behind schedule during certain hours of the day. If grounds maintenance is provided at two different bases, a SCM would not be happy with a sample which required 95% of the inspections at one base. Thus, a sampling plan must be devised which will "reasonably" represent the population of services. A general rule would be to adopt a selection method that will give every member of the population an equal chance of being selected. In general, it is best to use random numbers. These will hold up in court [Ref. 9].

2. Advantages

The use of random sampling as a quality assurance tool has inherent advantages over other inspection techniques. The most obvious is that it provides a cost effective way of estimating the true level of contractor performance. The fact that it may now be used as a basis for extrapolating deductions makes it all the more attractive. Some other benefits of random sampling offered by contract administrators are:

a) Requires less supervision of inspectors to make sure they are using their time effectively;

b) is not susceptible to the predictability which may be involved in planned sampling;

c) allows inspection of services to be transferred easily from one inspector to another as no previous knowledge of the contract is required.

NAVFAC has recommended that random sampling be applied to service contracts possessing the following characteristics: [Ref. 8]

a) Composed of a large homogeneous population of work units,

b) individual work items not of a critical nature,

c) population size estimable,

d) inspector travel time not excessive.

3. Problems in Practical Use

Although there would seem to be numerous advantages involved with the use of random sampling, even without extrapolated deductions, its use seems to be very limited within the NAVFAC community. Conversations with various

contract administrators indicate that a lack of familiarity with random sampling procedures, the complexity of writing amenable specifications, and the confusing guidance in the MO-327 are at the heart of their reluctance.

Probably the major impediment to instituting random sampling plans, with or without extrapolated deductions, is the lack of random sampling guide specifications for individual contract types. Contract administrators are either not willing or able to get bogged down in the details of generating performance specifications and quality assurance plans which properly incorporate random sampling. For that reason, a great many services amenable to random sampling are being inspected in a judgmental manner with poor performance defined as an intolerable level of customer complaints.

Janitorial services would seem to be a prime candidate for random sampling, yet interviews with contract administrators revealed confusion and frustration where attempts to write a suitable plan were made. This confusion is easily understood. Questions exist over what the sampled unit should be. Should it be individual rooms, groups of rooms, buildings, or the specific acts of emptying ashtrays and cleaning windows? Also, how is a representative sample taken when conditions vary? Suppose that a BOQ building is randomly selected for inspection. Can the percent of rooms

found to be nonconforming be used as an indicator of overall performance across the various buildings on base?

The design of random sampling plans is beyond the scope of this paper. It is addressed because of its discovery as an issue in the course of the research. Due to the complexities involved with designing random sampling plans and the lack of specific guidance, I would not be surprised if the majority of random sampling plans which in effect are of poor statistical validity. Contractors have had no reason to challenge these procedures either because they did not understand them, or because they were not being used as a basis for deductions other than observed deficiencies. It should be anticipated that the extrapolation of deductions will cause many of these sampling plans to come under intense scrutiny.

Another impediment to the use of random sampling has been the difficulty of generating random numbers and applying it to the population. Appendix B contains instructions from the MO-327, which provides the guidance for random sampling and tables for random number generation. Sample generation by the manual method can be seen to be time consuming and difficult to apply objectively. The tendency would be for users to become frustrated with unusable numbers and just resort to making up numbers on their own. While NAVFAC recognizes the shortcomings of the random number table and now advocates the use of computer programs

for generating samples, they still recommend the use of the tables where a computer and program are not available. [Ref. 19] I believe that a computer based system is a necessary part of establishing a viable program with complete command support.

C. EXTRAPOLATING DEDUCTIONS

1. Background

NAVFAC did not adapt the statistical methods of MIL-STED-105D for surveillance of NAVFAC service contracts because it called for acceptance of work at levels below 100%. Additionally, it allowed large deviations in the observed sample above the AQL before it was rejected. Reservations about the legality of extrapolated deductions was also expressed. [Ref. 20]

In 1983, NAVFAC adopted the thinking that extrapolated deductions would be an effective contractor motivator. It was also thought that it would provide an additional incentive for activities faced with scarce inspector resources and increasing levels of contracted services to adopt random sampling. The technique would be implemented when a methodology was available to take deductions fairly, with a high degree of confidence that they would not take the form of punishment. Dr. Douglas Montgomery of the Georgia Institute of Technology was hired as a consultant to develop a statistical basis and procedure for extracting

these deductions [Ref. 20]. Working with NAVFAC, a methodology was ready for field use in 1984.

The ultimate form that extrapolated deductions will take is still in doubt. NAVFAC is currently working on a new statistical basis which is more in line with its contracting philosophy. The elements of that methodology will also be looked at in this chapter.

2. Legal Considerations

The legal basis for extrapolating deductions is derived from the Federal Acquisition Regulations: [Ref. 21]

> If any of the services do not conform with contract requirements, the Government may require the contractor to perform the services again. . . . When the defects in services cannot be corrected by reperformance, the Government may . . . (2) reduce the contract price to reflect the reduced value of the services performed.

A key concept is that the reduction in price must correspond to the cost of the services. A case that applied this ruling was Environmental Aseptic Services Administration and Larson Building Care Inc. [Ref. 22]. This case involved an Air Force janitorial contract. The protesters complaint was that sampled services, which in this case was "cleaned rooms," subsumed several required tasks (e.g., aseptic floor, furniture, fixtures, drapes, and trash). The Performance Requirements Summary provided that if a task fails, the room failed for the day. In other words, if the contractor failed to clean the ashtrays, he would suffer the same deduction as though he had failed to perform all required tasks in the room. Thus the extrapolated deduction

greatly exceeded the value of the one task not performed. The GAO ruled in the case that the deduction was tantamount to a penalty, and its inclusion in the Invitation for Bids unnecessarily raises the governments cost and has an adverse effect on competition.

Closely tied to the issue of reasonable cost deductions is the treatment of liquidated damages. The Federal Acquisition Regulations state the following policy: [Ref. 23]

> Liquidated damages clauses should be used when both (1) the time of delivery or performance is such an important factor . . . that the Government may reasonably expect to suffer damage if the delivery or performance is delinquent and (2) the extent or amount of such damage would be difficult or impossible to ascertain or prove. . . . The rate of liquidated damages used must be reasonable and considered on a case-by-case basis. . . . Liquidated damages fixed without any reference to probable actual damages may be held to be a penalty and therefore unenforceable.

The Navy Contracting Manual, P-68, allows liquidated damages to be assessed o FSCs at the rate of 10% of the price of the service whether or not it is subsequently re-performed. The extrapolation of deductions has caused some confusion in this area. Do liquidated damages apply to the estimated portion of unperformed work?

Original NAVFAC guidance indicated that the extrapolation of liquidated damages was proper [Ref. 24]. Later guidance called for liquidated damages to be applied only to items re-performed, which would prohibit their extrapolation [Ref. 19]. More recent discussions with NAVFAC indicate

that the policy will be to take liquidated damages for observed deficiencies, whether or not it is subsequently re-performed.

The key question to be asked concerns the reason for liquidated damages. If it is to compensate the government for increased administrative costs associated with re-inspection, then it is appropriate to apply liquidated damages only in instances where the item is re-performed. However, if the basis of the liquidated damages is to compensate the government for the interruption of normal activities associated with dirty chalkboards and unemptied dumpsters, then re-performance is not a consideration and the damages remain. Also, the damages associated with the estimated portion of nonperformance would be just as real as the inspector observed deficiencies. The fact that NAVFAC now advocates that liquidated damages be applied for observed deficiencies would indicate the latter as a basis. Therefore, the extrapolation of liquidated damages would appear defensible in court. The greater amount of deductions assessed would also act as an enhanced motivating force.

Another important issue from a legal standpoint is the implications of not obtaining a sample by procedure. For example, suppose an inspector fails to obtain the sample required by procedure. Does that invalidate the sample for extrapolation purposes? From the standpoint of violating

the procedure itself, apparently not. The GAO has ruled that when regulations set out instructions clearly for the benefit of the government, the agency's failure to comply with it does not provide a basis for protest. [Ref. 25]

As far as the sample size itself, the government's failure to select an adequate sample has been the basis for upholding protests [Ref. 25]. However, that case involved a sampling scheme which was part of the contract. NAVFAC has no plans to make their quality assurance program a contract requirement. Even in the case where a sampling scheme has been included as a part of the specifications, the Armed Service Board of Contract Appeals has ruled that a deviation in sampling procedure is allowable where "no appreciable difference in results occurs" [Ref. 26]. I agree with the NAVFAC policy not to include quality assurance procedures in the contract. The government must reserve the right to remain flexible in this area. At the same time, contractually specified quality assurance would open up contract administrators to numerous protests.

D. STATISTICAL BASIS FOR FIELD TESTING

1. Introduction

The statistical method devised by D.r Montgomery for use in the NAVFAC field tests are easily incorporated into tables amenable for field use. These tables require no knowledge of statistics for application. However, a lack of appreciation for the relationships which form the basis of

the tables means that the potential for misusing them exists. Lacking specific guidance, activities may unnecessarily increase their administrative burden in cases of mismatched samples and populations. It should be emphasized that the motivation behind extrapolated deductions is to better match pay to services using minimal inspector resources. This section looks at the statistical basis of the field tests and discusses the various components upon which the tables are based.

2. Use of the Tables

Tables approved by NAVFAC for use in monitoring service contracts and taking extrapolated deductions were distributed to Engineering Field Divisions and Public Works Centers in 1984. Guidance in use of the tables (see sample tables in Appendix C) was provided by NAVFAC as follows: [Ref. 24]

> In order to use the tables, the user must first establish the "Critical Performance Level" (CPL) which is defined as the level of performance by the contractor that the government considers to be adequate and is expressed as a percentage. The CPL is established during the specification writing phase and should be entered into the Performance Requirements Summary. For a given CPL and population size, the tables give the user a sample size and a Critical Number of Defects (CND). The CND is the number of defects in the sample that would signal poor contractor performance and is the threshold for considering taking a deduction based on a statistically estimated number of defects. When the number of defects observed in the sample equals or exceeds the CND, the number of defects in the population is estimated by multiplying the population by the percentage of defects found in the sample. When the number of defects observed in the sample is less than the CND, deductions will be taken for observed defects only. . . . The Normal Surveillance Table will usually be used for a new contract. The Tight Surveillance Table

should be used if observed defects exceed two-thirds of the CND for two consecutive months. The Reduced Surveillance Table should be used if the observed defects are less than one-third of the CND for two consecutive months. Normally when Reduced Surveillance Tables are used, deductions will be taken for observed defects only.

Use of the term CPL (equal to 100-AQL) was NAVFAC's way of stating that 100% performance was being contracted for, but that a somewhat lower level would be tolerated before adverse contract action would be initiated. The inclusion of the CPL in the contract was NAVFACs first concession in writing that less than 100% performance was acceptable. This change in policy was made necessary by the fact that the CPL was the key factor in taking extrapolated deductions, and in the course of explaining deductions to the contractor it would have become known anyway.

Opinion is mixed whether or not the CPL being part of the bid package would lead to lower bids by contractors planning to under-perform. The incentive to do so would seem to be there. For example, if the CPl was 90%, a contractor could cut his bid by 10% and plan to only perform 90% of the work. If he could maintain his actual performance at 90%, he could avoid extrapolation 95% of the time. Although he would have to rework observed deficiencies or suffer the specific deductions, these would only be a small percentage of the actual deficiencies which existed. The result of all this would be a borderline contractor with high administrative costs. This possibility points out a weakness of including the CPL in the contract under this

type of system. Limiting the CPL to the QA plan would allow it to be changed at a later date if it became necessary.

It should be noted that the method approved is very similar to that used by the Air Force. For a given performance requirement and population size, a CND (reject number) is established at which time extrapolation can be applied. The major procedural difference is that below the CND the Navy would still deduct for observed defects, while the Air Force did not. This difference was due to the Navy's basic requirement being 100% performance.

3. Mathematical Basis of Field Method

The mathematical basis of the tables used for the field test is the normal approximation of the hypergeometric probability distribution. The sample sizes shown in the tables were calculated using the relationship of equation (1):

$$n = \left[\frac{W^2}{Z^2(CPL)(1-CPL)} + \frac{1}{N}\right]^{-1} \qquad (1)$$

where:

n = required sample size

CPL = critical performance level

N = estimated population size

Z = normal one-sided z-statistic

W = width of the confidence interval = (1-CPL)/2

The z-statistic is dependent on the confidence level desired. For normal inspection the confidence level is 95% and the corresponding z-statistic is 1.645. This means that the resulting sample will ensure that the observed defect rate is within the specified confidence interval 95% of the time. Tightened inspection equals 99% confidence, while reduced equals 90%.

4. Effect of CPL

The confidence interval (W) can be seen to be a function of the CPL. It is perhaps easier to think of it as one-half the allowable defect rate. Thus the greater the CPL, the more narrowly defined is the confidence interval, and the greater is the sample size required. This relationship may be undesirable due to the lack of specific guidance in setting CPLs. Contract administrators have interpreted the CPL to be a level of acceptable performance from an average contractor. Thus easily performed services should rate a high CPL regardless of the importance of the service. Because the confidence interval then becomes such a small number, which is subsequently squared, it has an overriding effect on the sample size. From the normal table (see Appendix C) it can be seen that if the population estimate is 1000 units of work, a shift in the CPL from 90% to 95% would result in the required sample size being doubled.

If the confidence interval is going to vary inversely with the CPL, a distinction should be made between

"critical" services and those which happen to rate a high CPL due to the ease with which they can be performed. Perhaps the latter category could be inspected at a reduced level of confidence. This would be consistent with the efficient use of inspector resources.

The use of the CPL term in equation (1) is only a best estimate of actual performance, which is what is actually mathematically required to make the equation valid. If the actual performance is less, the actual confidence level achieved will be less. NAVFACs rationale for accepting lower confidence levels when contractor performance is below the CPL is that greater attention will be focused on the contractor's performance by various other methods. A plot of this relationship for a 95% confidence level (normal surveillance) and CPLs of 90% and 97% is shown in Figure 4.1, a population of 300 was assumed. It can be seen that achieved confidence at realistic performance levels still gives the benefit of the doubt to the contractor. Therefore, whether or not other actions are anticipated, very poor performance does not invalidate extrapolation.

5. Effect of Sample Size

In Section C-2 of this chapter, the implications of not taking the appropriate sample size was discussed. Figure 4.2 shows a plot of the relationship between sample size and confidence level for populations of 100 and 500,

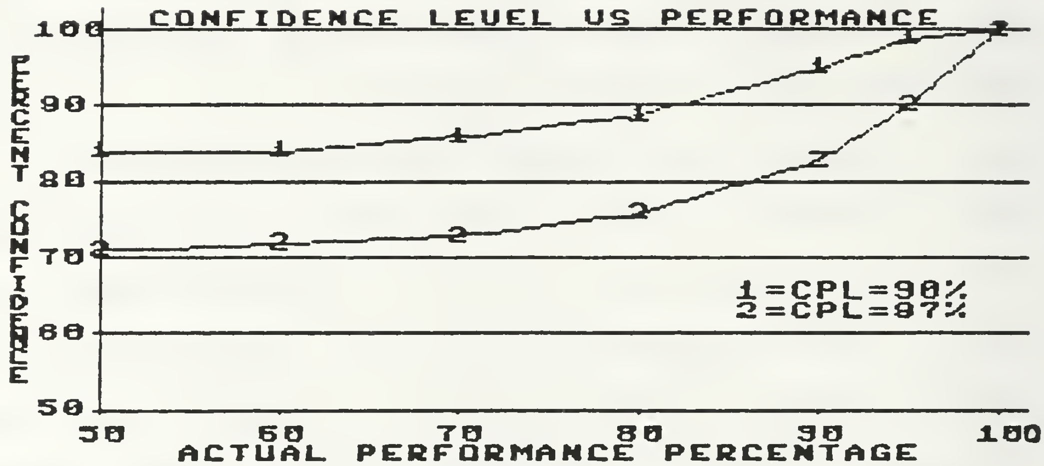


Figure 4.1 Confidence Level as a Function of Performance

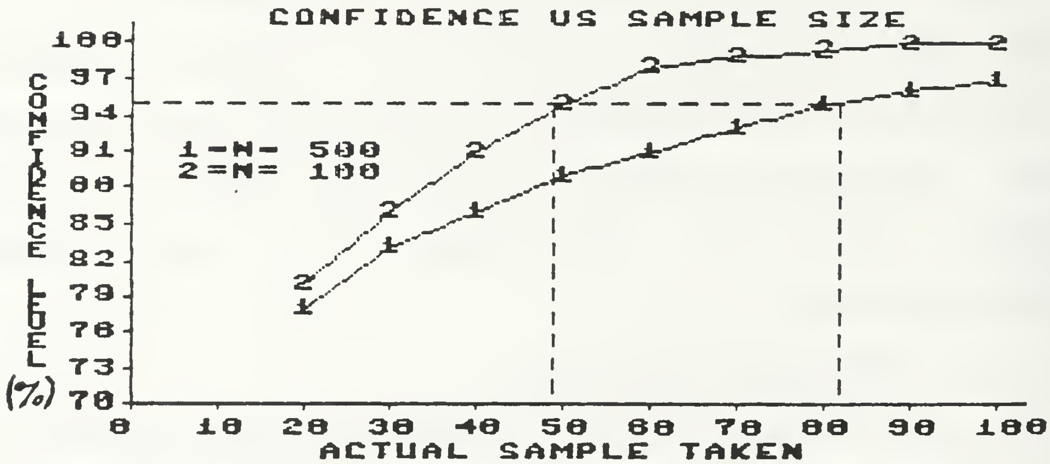


Figure 4.2 Confidence Level as a Function of Sample Size

normal sampling and a CPL of 90% are assumed. Where actual samples fall below the required sample, achieved confidence gradually decreases. This is especially true where large samples are involved. For example, if the sample taken for a population of 500 was only half the required 82, achieved confidence would still be in excess of 86%. It can be concluded that failure to reach a designated sample is probably not going to appreciably affect the results. Therefore guidance on this matter should be promulgated to avoid the situation of activities invalidating their samples when there is no need to do so.

6. Effect of Population Estimate

Similar to the situation of not obtaining the proper sample size is the almost monthly problem of not properly estimating the population size. Analysis of the relationship between confidence level and population size shows that this situation is of almost no consequence. Take the case where the estimated population is 500 units and the desired confidence level is 95% (CPL = 90%, sample size = 82). If the actual population turns out to be 400, the resulting confidence level will be 95.5%. At an actual population of 600, the original sample of 82 will still give a confidence level of 94.7%! In fact, whenever the original sample size is greater than about 30, the achieved confidence level should be sufficient to support extrapolated deductions using the original CND. Again, there is no guidance on this

matter and activities may try to unnecessarily match sample sizes to ultimate populations at the expense of manpower and possibly statistical validity. It would appear to be the case that in all situations where random sampling is appropriate, the original sample should be sufficient to support extrapolated deductions or any other contract action.

7. Operating Characteristics

The CND is calculated by determining the defect rate which exceeds the CPL plus the confidence interval at the specified confidence level. Equation (2) illustrates this relationship:

$$\text{CND} = n[\text{CPL} + Z\sqrt{\frac{(\text{CPL})(1-\text{CPL})}{n}(1-\frac{n}{N})}] \qquad (2)$$

The application of equation (2) is equivalent to a standard hypothesis test. The statement being made at a normal level of inspection is that if the CND is reached, we are 95% confident that the actual defect rate is equal to or greater than the allowable defect rate.

Figure 4.3 contains an operating characteristic curve for various CPLs. It can be seen that while this methodology is biased toward the contractor, it does exhibit higher levels of producer risk than MIL-STD-105D. A good point of comparison is an actual performance rate of 85% and a CPL of 90% (AQL = 10%). The NAVFAC statistical basis will accept this level of performance just over 50% of the time,

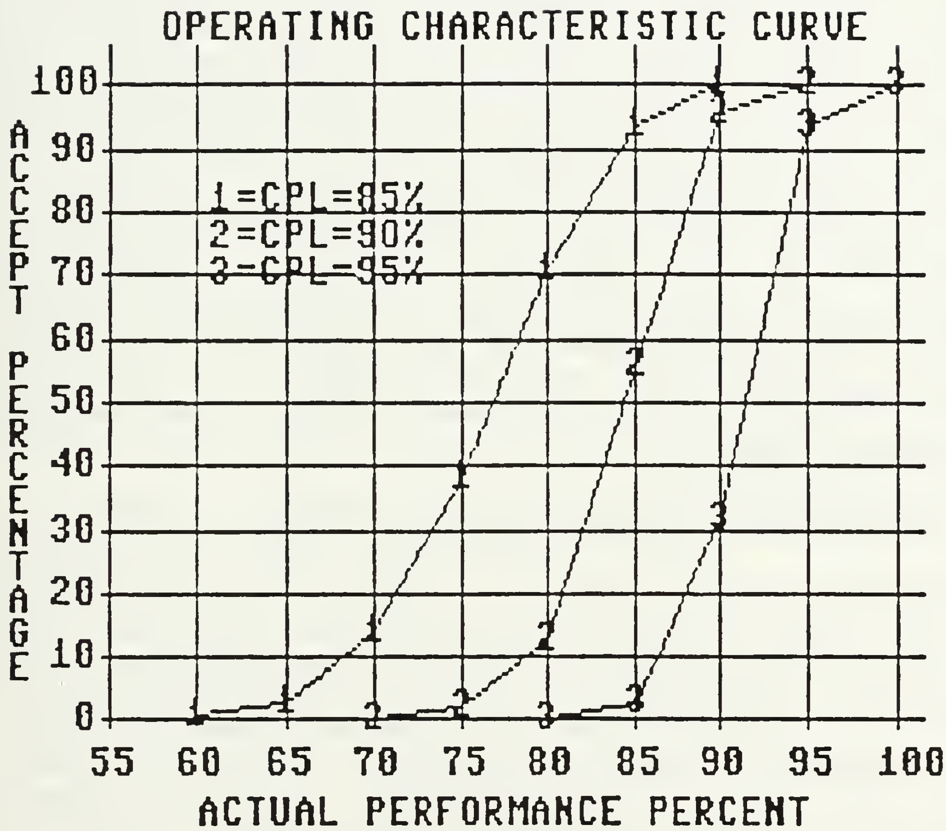


Figure 4.3 Characteristics of Normal Sampling, sample=50

while the Air Force would accept it 85% of the time using MIL-STD-105D (see Appendix A for MIL-STD-105D).

E. PROPOSED STATISTICAL BASIS FOR FUTURE USE

A problem with the statistical basis used in the field tests, as viewed by NAVFAC, is that it did not allow for extrapolation until contractor performance was below the CPL. This implied that performance above the CPL was acceptable. Yet NAVFAC is adamant that service contracts be written for 100% performance. Thus, a new method for taking extrapolated deductions is being developed by NAVFAC. It is planned that when ready for field use, this method will replace the method used in the field tests. This section describes the characteristics of the new method as it currently exists.

The proposed statistical basis for taking extrapolated deductions in the future is more in line with NAVFAC's policy of contracting for 100% performance and taking deductions where evidence of nonperformance exists. Code named RSED V3.0, this methodology seeks to determine the contractor's actual level of performance. Deductions are then extrapolated without regard to a CPL. The concept of a CPL is utilized to the extent that if a contractor's performance does not meet the CPL, as determined by the ODR, contract actions in addition to payment deductions are indicated. These CPLs are to be included in the contracts Performance Requirements Summary. [Ref. 19]

RSED V3.0 has not been finalized for field use. Preliminary indications are that it will incorporate one basic sampling level, although others may be added. The defect rate determined by the sample is adjusted downward by a specified "delta" depending on the observed defect rate to determine a level appropriate for deductions. The use of the delta ensures that the deduction rate will be less than or equal to the contractor's actual defect rate 75% of the time on a monthly basis, and approximately 90% of the time over the annual contract term. The higher confidence level associated with the contract term is felt by NAVFAC to be the minimum necessary for which to base stronger contract actions such as termination or not renewing options. Appendix D contains the sample size and delta tables along with a sample payment analysis reproduced from NAVFAC documentation. [Ref. 19]

Like the model used for field testing, RSED V3.0 uses the normal approximation of the hypergeometric distribution to determine sample sizes and confidence intervals. The relationship used for calculating sample sizes is identical to the field model except that different assumptions are made. Equation (3) illustrates:

$$n = \left[\frac{W^2}{Z^2(P)(1-P)} + \frac{1}{N}\right]^{-1} \qquad (3)$$

where:

n = required sample size

W = .01 (a fixed value of 1% regardless of CPL)

P = .95 (a fixed value of anticipated performance, not CPL)

Z = .674498 (normal z-statistic for 75% certainty)

N = estimated population size

Equation (3) can be rewritten as,

$$n = \left[.00462749 + \frac{1}{N}\right]^{-1} \qquad (4)$$

The resulting sample size can be seen to be independent of the CPL. It will yield an observed defect rate within 1% of the actual defect rate 75% of the time, provided the actual performance is close to the estimate of 95%. At the end of the month, the observed defect rate is used as a better estimate of actual performance to calculate a new confidence interval. This new confidence interval is found by solving Equation (1) for "W". The new value for "W" becomes the "delta" adjustment. Equation (5) illustrates:

$$\text{DELTA} = Z\sqrt{\frac{P(1-P)}{n}\left(1 - \frac{n}{N}\right)} \qquad (5)$$

where:

P = observed defect rate (ODR)

Z = 1.28159 (normal z-statistic for 95% certainty)

N = 12,000

n = 732

The "delta" is calculated with fixed values of "N" and "n" so that one table which is a function of the observed defect rate may be utilized. This simplification results in deltas approximately one percent less than would have been obtained using actual sample sizes and populations. It also precludes the necessity of having a table for each possible sample size and population! The delta in conjunction with the ODR can now be used to estimate the true level of contractor performance, and to determine a deduction rate to be used for extrapolation. The following statements help summarize the results of this methodology using an ODR of 10% as an example: "We are 75% confident that the true defect rate is greater than the deduction rate of 8.62% (ODR-DELTA),: or for evaluating performance, "We are 75% confident that the true performance level of the contractor is less than 91.38% (100% - ODR + DELTA)."

F. COMPARISON OF THE TWO STATISTICAL BASES

1. Inspection Requirements

The proposed statistical basis will require greater sample sizes to be inspected than the field version. This is due to the fact that RSED V3.0 seeks to ascertain actual contractor performance within a tolerance of one percent. Because extrapolation will be applied at all levels of

performance under RSED V3.0, this small confidence interval is deemed necessary by NAVFAC. Since the field version is designed only to determine whether actual performance is less than a "tolerable" level, it can be done with a smaller sample at a higher level of confidence.

Another difference between the methods is the greater flexibility allowed with the field version. Depending on inspector resources and contractor performance, SCMs can direct inspection at three confidence levels with large differences in inspection requirements. In addition, different CPLs can be assigned to further adjust inspection requirements within the different levels. However, the large influence on inspection requirements exerted by the CPL may cause some contract administrators to specify a performance level lower than actually desired. Under normal levels of inspection, specifying a 95% CPL over a 90% CPL results in almost doubling the sample size. The potential thus exists for contract performance requirements to become a function of inspector resources.

Increased flexibility could be built into RSED V3.0. This would have to be done by allowing different confidence intervals, since the confidence level of 75% would seem to be approaching a minimum. Specifying larger confidence intervals would not change the ODR, which will be the basis for contract actions other than extrapolation and remains the best estimate of contractor performance. Also, the fact

that straight line deductions exist in the Air Force where contract specifications have not been met, implies that NAVFAC is being unnecessarily conservative.

2. Effect On Contractor Performance

It is reasonable to assume that the contractor will be motivated closer to 100% performance under RSED V3.0. However, most contract administrators feel that 100% performance is unrealistic for most services, and expressed the opinion that public works forces rarely performed at the now specified CPL. The extrapolation of deductions at performance levels which have been previously considered satisfactory represent a source of increased risk to the contractor which may be expected to result in higher bid prices.

Bid prices may also be higher under RSED V3.0 for a more positive reason. The feature of extrapolating at all defect levels means that there is a much closer match between payment and services received. Contractors will not have any incentive to underbid the contract with the goal of performing at the CPL and avoiding extrapolation. Thus RSED V3.0 might result in more bids where the contractor is able to make a fair profit at the required performance level. Whether or not this results in higher overall bids depends on the profit levels now being enjoyed by service contractors.

There seems to be a greater potential for an adversarial relationship to develop between the contract administrators and contractor under RSED V3.0. This is because every observed deficiency would have ramifications beyond its own merits. Under the field method, this wasn't the case until the CND was reached. At that point there was little room for sympathy because the contractor was performing at levels well below specified levels. Because the quality of services is subject to some inspector judgment, borderline cases under RSED V3.0 may be dismissed as inspectors carry the increased burden of identifying discrepancies which will be the basis for extrapolation.

3. Deduction Level

There are too many variables involved to try and quantify the anticipated differences in deductions which would be obtained using the two statistical methods. It would be fair to say that the potential for higher deductions exists under RSED V3.0. The dichotomy remains that when either system is functioning as intended, the deductions will be at a minimum.

A major difference between the two methods is the treatment of discrepancies outside the random sample (e.g., customer complaints, planned sampling). When deductions are extrapolated, it is not correct to also deduct for deficiencies found outside the sample, as these would be theoretically included in the extrapolated results. Since

RSED V3.0 extrapolates from the start, it is never permissible to deduct for a customer complaint. The field method would allow this deduction if the CND had not been reached. An interesting result is that in services which are customer oriented and a strong customer complaint program exists, extrapolated deductions under RSED V3.0 could easily be less than what would have been obtained by deducting for known deficiencies. This does not appear to be a situation that the contractor can take advantage of. Even if the services were not amenable to re-work, contract actions other than extrapolation could be resorted to.

4. Producer/Consumer Risk

Both the field version and RSED V3.0 are biased towards the contractor. The field version allows actual defect rates to be approximately 1.5 times the CPL before an even chance of rejection occurs and straight line extrapolation is applied. Performance levels under RSED V3.0 are closely determined, but then a "delta" subtracted from the ODR assures that the contractor will be overpaid in the long run.

A normal approach to comparing the producer bias inherent in any statistical techniques is the operating characteristic curve. However, since there is no reject number (CND) involved with RSED V3.0, a curve for it cannot be constructed. It is safe to say that in either method, the contractor is treated more than fairly. A theoretical

even treatment would be to apply the ODR as a deduction rate at any performance level. However, NAVFAC is not willing to live with the idea that in any one month, the contractor has an even chance of being overpaid or underpaid, least not at reasonable inspection levels (confidence intervals).

5. Ease of Use

Both methods appear workable and of comparable difficulty to implement and administer. However, under RSED V3.0 required sample sizes are specified for much narrower population ranges. This increases the potential for mismatched samples with actual populations. If clear and simple guidance isn't promulgated which defines actions to be taken when procedures aren't strictly followed, the administrative burden could become excessive.

V. SURVEY OF FIELD TESTS

A. INTRODUCTION

1. Purpose

The purpose of this survey is to identify general issues which should be addressed before the extrapolation of deductions is approved for general use. Although both of the field tests involved family housing maintenance contracts, the focus of this study remains oriented toward general issues. Preferred methods for applying extrapolated deductions to any specific contract type are outside the scope of this work.

2. Background

The two activities involved in the field test are Public Works Center (PWC) Great Lakes and PWC San Francisco. Although the housing maintenance requirements of each activity are similar, many differences exist regarding both the circumstances of the contracting effort and the approach taken to employ extrapolated deductions. Key differences include CPL requirements, performance weighting, and the method for classifying service work for bid and inspection purposes.

Both maintenance contracts were initially written as the basis for a CA review. In the case of San Francisco, the contract ran for two years before approval to use

extrapolated deductions was granted in July, 1985. Prior to that time, random sampling had been conducted using the procedures of MO-327.

At Great Lakes, extrapolated deductions was a part of the contract from its inception in 1984. NAVFAC provided assistance in developing contract specifications, but the QAP and related payment documents were generated in-house from scratch. The methodology for taking deductions was approved at the NAVFAC level before extrapolation was allowed.

3. Data Collection

The collection of quantitative data was made difficult due to the great amount of paperwork which is generated over the course of administrating a service contract. I was limited to using payment summary sheets because of the fragmentary nature with which relevant information is located within that paperwork. These summaries were not directly comparable, so some information obtainable at one activity could not be collected at another. One example was an inability to determine the percent of rework accomplished at Great Lakes. This prevented a deduction comparison with RSED V3.0 at that activity, which was done with the PWC San Francisco data.

Data collection was focused in both cases on performance, inspection and payment history of service work. Service work is normally customer generated and requires

less than 16 hours to complete. It constitutes the largest component of work performed under a housing maintenance contract, approximately half. Random sampling was applied to service work for the purpose of extrapolating deductions at both activities. Other major portions of housing maintenance includes change-of-occupancy work and preventive maintenance. Data on these categories of work was not collected because the change-of-occupancy work is 100% inspected and the preventive maintenance data was not easily summarized.

Data collected at PWC San Francisco represented a contract period of 11 months. Data collected at Great Lakes extended over a 24 month period. In addition to a collection of historical data, interviews were conducted with contract administrators at both activities.

B. CONTRACT REQUIREMENTS

1. Treatment of Service Calls at Great Lakes

Service calls at Great Lakes were classified as either emergency, urgent, or routine. The implication for the contractor was that each required different response times. The definitions of each category are given below along with the required response time.

> EMERGENCY CALLS--These are problems which pose an immediate danger to the occupants or have the potential to cause further property damage (e.g., power lines down, overflowing toilet). They require contractor response within 30 minutes on a 24 hour basis.

URGENT CALLS--These are problems which do not pose an immediate threat to occupants or property, but would soon inconvenience and affect the well-being of the occupants (e.g., refrigerator not working, toilet backed up). The contractor is required to respond within two hours of the call.

ROUTINE CALLS--These are problems which cannot be classified as either an emergency or urgent situation (e.g., tile repair, binding doors). The contractor is required to respond within nine days and to complete the work within 14 days.

The performance of service calls was broken down into four performance indicators: responsiveness, quality of work, proper classification, and proper accounting. Each one of the performance indicators was assigned a weighting representative of the "worth" of that portion of the job. Performance weights must total 100%. When performance indicators are weighted, it means that accomplishment of any individual performance indicator earns a percent of the service price equal to the weighting. Thus, weighting has a direct bearing on the level of deductions to be assessed for failure to perform. For example, the performance weighting for emergency response is 45%. Suppose that a contractor responded to an emergency call one hour late. Regardless of the fact that quality work was done and the job was properly documented, 45% of the price would be subject to deduction.

2. Treatment of Service Calls at San Francisco

Service calls at San Francisco were also categorized as emergency, urgent and routine. However the required response times differed as follows:

EMERGENCY CALLS--two hours during work hours, four after;

URGENT CALLS--twenty four hours;

ROUTINE CALLS--five days response, fourteen days completion.

San Francisco also used the same four performance indicators as Great Lakes, but did not assign weights to them. In effect, that meant that each one was weighted 100%. A deficiency in response time, quality, or documentation would result in a total deduction being taken.

Another difference between the activities was that San Francisco combined its service calls into three other categories for the purpose of bidding and inspection. These were interior, exterior and appliances. Thus, exterior work might consist of any of the three service call types.

C. QUALITY ASSURANCE PLANS

1. Introduction

Quality Assurance Plans (QAP) are long, complex documents which attempt to provide the activity with a structured approach for inspecting all aspects of a contractor's performance. It is beyond the scope of this paper to attempt to convey the contents of either activity's QAP. My intent is to report only those findings which have general applicability to RSED.

2. General Comments

A major difference between the two plans was that PWC Great Lakes wrote theirs initially to incorporate RESED.

San Francisco's plan was based on the MO-327 version of random sampling, which did not allow for extrapolation. The result was that the QAP in San Francisco had little resemblance to the quality assurance program which eventually evolved. The fact that PWC San Francisco was able to implement a workable program after some trial and error, reinforces the wisdom of separating the QAP from the formal contract.

3. Critical Performance Levels

The CPLs contained in the QAP were not part of the bid information of either contract. NAVFAC's policy then, which has just recently changed, is that the CPL was an in-house tool only. However, while unknown to the contractor during the bidding process, the contractor soon became familiar with the CPL as it formed the basis of payment analysis and performance judgments.

The CPL assigned to service contracts in San Francisco was 90%, while Great Lakes enforced a CPL of 97%. San Francisco felt that a CPL in excess of 90% was too harsh and unrealistic. The opinion at Great Lakes was that 97% performance was realistic and had been achieved by the departing public works force. The SCM at Great Lakes also felt that a 97% CPL was high enough to prevent planned noncompliance by the contractor. A possibility he thought plausible at a CPL level of 90%.

The actual weighted average performance or service calls achieved at PWC San Francisco was 92.0%, as compared to 98.1% at PWC Great Lakes. While contractor performance is subject to many variables, including inspector aggressiveness, the close parallel between performance differences and CPL differences suggests a relationship.

4. Performance Weighting

The failure of PWC San Francisco to weight the different aspects of service call performance for payment purposes would probably have made extrapolation unsupportable in court. This is similar to the Air Force janitorial contract [REf. 2]] where a room could be declared unsatisfactory and payment denied because an ashtray was not emptied.

Not weighting performance factors also makes bidding more difficult and transfers greater risk to the contractor. This may have been a factor in PWC San Francisco paying a weighted average of $55.00 per service call, while Great Lakes paid only $33.00.

There was not enough data to support conclusively whether or not weighting influenced contractor performance at Great Lakes (see performance weights in Figure 5.1). However, in emergency and urgent calls where responsiveness and quality were closely weighted, mean performance was within one half of a percent of each other. In the case of routine calls, where quality carried twice the weight of

	RESPONSE	QUALITY	CLASSIFICATION	ACCOUNTING
EMERGENCY CALLS	.45	.45	.02	.08
URGENT CALLS	.40	.50	.02	.08
ROUTINE CALLS	.30	.60	.02	.08

Figure 5.1 Percent Performance Weighting at PWC Great Lakes

responsiveness, quality performance exceeded responsiveness by 4.3%.

D. INSPECTION REQUIREMENTS

1. Introduction

This section looks briefly at the use of inspector resources at each activity. Any random sampling program approved for extrapolated deductions must permit efficient use of inspectors, with minimal administrative burden, if it is to receive command support. Although many of the inspection procedures referred to are in the QAP, all inspection related information is presented in this section for clarity.

2. Sampling Levels

Figures 5.2 and 5.3 show the monthly level of inspection employed at each activity over the period studied along with the population range for each of the service categories. It should be noted that due to the lower CPL, inspection levels at San Francisco were far below that of Great lakes. In fact, although the number of calls at San Francisco are higher, they inspected less than half the calls inspected at Great Lakes. This relationship would suggest too great an incentive for contract administrators to sacrifice performance requirements for the sake of saving inspector resources.

These figures also show the potential savings possible by combining the services into one group for

	POPULATION MEAN	POPULATION RANGE	SAMPLE MEAN	INSPECTION LEVEL
ROUTINE CALLS	536	391-713	207	39%
URGENT CALLS	470	381-604	163	35%
EMERGENCY CALLS	165	110-250	97	59%
TOTAL	1171	950-1391	467	40%

Figure 5.2 Inspection Data at PWC Great Lakes

	POPULATION MEAN	POPULATION RANGE	SAMPLE MEAN	INSPECTION LEVEL
INTERIOR CALLS	961	814-1070	88	9%
EXTERIOR CALLS	280	173-435	69	25%
APPLIANCE CALLS	192	139-229	64	34%
TOTAL	1433	1252-1669	221	15%

Figure 5.3 Inspection Data at PWC San Francisco

inspection purposes. If the population of service calls at San Francisco were combined into one group of 1433 calls, the required sample size would only be 91!. Whether or not this could reasonably be considered a homogeneous population is subject to debate. Differences in frequency or cost is no greater than the variation which occurs within each service call category. The economy inherent in large populations argues for combining work items where possible.

A look at the population ranges in Figures 5.2 and 5.3 illustrates the difficulty in estimating an appropriate sample size. Another benefit to increasing the population is the greater stability involved. A sample size of 91 would apply to all populations in the range of 1300-1500.

3. Surveillance Level Switching

Both QAPs provided conditions under which surveillance levels could be changed. At PWC San Francisco, the option was not exercised for two reasons: (1) contract administrators felt that reduced inspection levels would not have been adequate, and (2) tight surveillance was beyond the capacity of the inspector force.

Surveillance levels were switched as deemed appropriate by the SCM at PWC Great Lakes. Although the guidance in the QAP was not strictly followed, the switching technique was effectively utilized. Even within the routine service work category, different surveillance levels were used for a period of time. Response time was under tight

inspection, while quality of work was inspected under reduced surveillance. It should be remembered that the incentive for going to reduced inspection was much greater at Great Lakes. Even under reduced inspection, at a 97% CPL level, greater inspection was required than normal inspection at San Francisco.

The switching of inspection levels does present a problem in balancing the workload. The SCM at Great Lakes claimed that he was staffed for a normal inspection load. When tight inspection was implemented, as it was for the first year under routine response, it could be covered only through the use of overtime and the shifting of inspectors from other assignments. In my view, the only thing gained by tightened inspection is the ability to extrapolate the same percentages at a higher confidence level and a few more observed deficiencies. It would seem more efficient to stay at normal inspection for extrapolation purposes and use planned inspections where it was necessary to prod the contractor a little further. Planned inspections on a limited basis can usually be done so that the incidence of deficiencies is enhanced. Also, these extra planned inspections would not be a firm requirement and would thus allow extra flexibility. While deductions resulting from planned inspections are allowed only if extrapolation does not take place, the rework requirement is still enforceable.

4. Sample Generation

Both activities made use of a computer program to generate random samples. At the beginning of the month, the computer would generate the random numbers and these would be matched to service call chits as they came in.

The better program was in use at Great Lakes in that it did not require the use of tables (see tables in Appendix C). Required input consisted of a population estimate, CPL, surveillance level and lowest sample number. At San Francisco only the population estimate and sample size was required for input, but determining the appropriate sample size required using the tables. Aside from the enhanced possibility of making a mistake, the stratification of the tables normally meant that required samples were slightly greater than if determined directly by formula. In addition, the San Francisco program always generated numbers starting from one, which meant that chits needed to be renumbered every month.

5. Sample Adjustment

The question of sample adjustment arises when the actual population of services in a month requires a different sample than the one obtained as a result of the prior estimate of the population. At PWC San Francisco, this possibility was not addressed in the QAP. Lacking clear guidance, command procedure has been to evaluate the sample as if the population estimate had been correct. This

is a simplifying procedure based on conserving inspector resources. In evaluating the sampling history, this experience has been justified. Due to the relatively large samples involved, the lowest being appliances at a mean of 64 inspections per month, little change in confidence levels would have been gained by doing additional sampling. There was not time where an adjustment could have resulted in extrapolation.

The procedure written for PWC Great Lakes was more sophisticated, yet was unnecessary. At the end of the month, the QAE adjusted the sample size using the computer program. By giving it the same "seed" number, it automatically generated a new sample which either adds a few numbers to the previous sample or deletes a few. The QAE would then either inspect the additional samples or invalidate some already inspected for purposes of extrapolation. It is never desirable to invalidate a sample, as this only reduces the confidence level of the results.

As practiced, the SCM decides whether or not to do sample adjustment based on the possibility of extrapolation. Where the number of defects is close to the CND, he will authorize a sample adjustment. Even this procedure is not always prudent. Suppose the estimated population for emergency calls is 175. At a CPl of 97% and normal surveillance, this would call for a sample size of 117 and a CND of six. If the population turned out to be 200, it would call

for a sample size of 127 and a CND of seven. Assuming the original number of defects found was six, the inspector would be sent out to sample ten more jobs in search of one more defect. However, had extrapolation been assessed on the basis of the original sample, the unsatisfactory determination would have been made at a confidence level of 93%. Certainly this is good enough to ascertain unsatisfactory performance. Assuming that the original estimate had been made in good faith, this extrapolation would no doubt have been upheld in court. It would appear that guidance is necessary in this area, so that activities can make the most intelligent use of their resources.

E. PAYMENT ANALYSIS

1. Introduction

Payment analysis at both activities was based on general NAVFAC guidance issued early in 1984 [Ref. 24]. Each activity modified the guidance slightly to make it more applicable to payment for service call work. This section evaluates the methodology of taking extrapolated deductions at each activity. The deductions which resulted are then analyzed in light of the performance realized.

2. Payment Methodology

Figure 5.4 is an example of payment analysis for emergency service calls at Great Lakes. The procedure followed at San Francisco is illustrated by a reproduction of the payment calculation for exterior maintenance in

EXAMPLES OF PAYMENT COMPUTATIONS
Based on $5,000.00 per month for ESC

	Work Requirement	*Response Time	Classification	Cost Accounting	Quality Work
A.	Cost of Required Services	$2,250.00(45%)	$100.00(2%)	$400.00(8%)	$2,250.00(45%)
B.	Quantity of Required Units of Work	100	100	100	100
C.	Cost per Unit of Work	$22.50	$1.00	$4.00	$22.50
D.	Critical Performance Level (CPL)	97%	97%	97%	97%
E.	Critical Number of Defectives (CND)	4	4	4	4
F.	Sample Size (from "Normal" table)	78	78	78	78
G.	Observed Defective Units	0	0	2	10
H.	Percent Defective Units in Sample	0	0	3%	12.8%
I.	Deduct for Defective Units				
	(1) If G is less than E (G x C)	0	0	$8.00	N/A
	(2) If G is not less than E (H x A)	N/A	N/A	N/A	$288.00
J.	Deduct for Liquidated Damages (I x 10%)	0	0	.80	28.80
K.	Units Reworked	0	0	2	0
L.	Payment for Rework (K x C)	0	0	$8.00	0
M.	Payment for Service (A - I - J + L)	$2,250.00	$100.00	$399.20	$1,933.20
N.	EPS Deductions for poor or partially performed work which was not considered an Observed Defective Unit	0	0	0	0
O.	Deduct for Liquidated Damages (N x 10%)	0	0	0	0
P.	Payment for Services	$2,250.00	$100.00	$399.20	$1,933.20

Figure 5.4 Emergency Service Call Payment at PWC Great Lakes

October, 1985. This calculation is shown in Figure 5.5. The obvious difference between the two is that performance weighting requires separate analysis for each performance indicator at Great Lakes.

The wording of line "I" instructions (see Figures 5.4 and 5.5) was found to have caused problems at both activities. Line "I", as used at Great Lakes, is identical to NAVFAC guidance. However, the confusing instructions caused an inspector to not extrapolate deductions when the observed defects equaled the CND.

The instructions associated with line "I" at San Francisco leaves no clue as to what the actions should be when the observed defects equal the CND. In the one instance where the situation occurred, deductions were not extrapolated when the observed defects equaled the CND. Contract administrators were unaware of the proper procedure to follow in this case. Clearer instructions should advocate extrapolation when the, "observe defects are equal to or greater than the CND."

3. <u>Treatment of Liquidated Damages</u>

Liquidated damages were extrapolated at both activities (see Figures 5.4 and 5.5). The SCM at Great Lakes justifies this action by claiming that the customer suffers damages through the failure of the contractor to perform. This issue remains unresolved. In their new contracts, San Francisco will continue to extrapolate

	EXTERIOR SERVICE CALL DEDUCTIONS	
A.	COST OF REQUIRED SERVICES	$17,809.09
B.	TOTAL UNITS OF WORK	262
C.	COST PER UNIT OF WORK	$64.94
D.	CRITICAL PERFORMANCE LEVEL (CPL)	90%
E.	CRITICAL NUMBER OF DEFECTS	12
F.	SAMPLE SIZE	72
G.	NUMBER OF OBSERVED DEFECTS	15
H.	PERCENT OF DEFECTIVE UNITS IN SAMPLE	20.8%
I.	DEDUCTION FOR DEFECTIVE UNITS	
	(1) If G is less than E (GXC)	NA
	(2) If G is more than E (HXA)	$3,704.29
J.	DEDUCTION FOR LIQUIDATED DAMAGES (IX10%)	$370.43
K.	NUMBER OF RANDOM SAMPLE UNITS REWORKED	15
L.	PAYMENT FOR REWORK (KXC)	$974.10
M.	NUMBER OF VALIDATED CUSTOMER COMPLAINTS	7
N.	COST OF CUSTOMER COMPLAINTS (MXC)	$454.58
O.	LIQUIDATED DAMAGES FOR CUST COMP (NX10%)	$45.46
P.	CUSTOMER COMPLAINTS REWORKED	2
Q.	PAYMENT FOR REWORK	$129.88
R.	DEDUCTIONS FOR CUST COMPLAINTS (N-O-Q)	$370.16
S.	TOTAL DEDUCTIONS (I+J+O+R)	$4,444.88
T.	PAYMENT FOR SERVICES (A-S)	$13,364.21

Figure 5.5 Exterior Service Payment at PWC San Francisco

liquidated damages, while Great Lakes will claim liquidated damages only for work which is re-inspected.

A firm policy needs to be established for each category of work. Where a government function is the recipient of the service, as in a janitorial contract, extrapolated damages may be more easily supported. This is a different situation than attempting to assess damages for the housing occupants' inconvenience. In any case, the extrapolation of liquidated damages can be used as extra incentive to obtain contractor compliance with the contract.

4. Treatment of Validated Customer Complaints

Both activities took deductions for validated customer complaints in addition to extrapolation. This procedure is incorrect. The extrapolation of deductions theoretically accounts for all deficiencies which exist outside the sample. The most advantageous way to treat validated customer complains under the field version is to take deductions unless the CND has been reached. As can be seen in Figure 5.5, PWC San Francisco makes no such distinction.

5. Deduction Data

Extrapolation occurred ten times at PWC Great Lakes and only once at PWC San Francisco, although each lost an additional opportunity to extrapolate when the observed defects equaled the CND. The difference can be attributed mainly to the lower CPL used at San Francisco. However,

it's the potential of extrapolated deductions that is being counted on to improve contractor performance. Greater deductions are not being sought for their own sake. This potential is evident by analyzing the nature of the deductions.

A total of $19,195.00 was taken in service call deductions over the 24 months evaluated. That represents 2.1% of the contracted price for these services. Forty-five percent of those deductions, $8,694.00, were attributable to extrapolation beyond observed defects.

While only one incident of extrapolation took place in eleven months at San Francisco, it resulted in deductions of $2,731.00 above the observed deductions. That represented 23% of the total deductions of $11,768.00. Total deductions at San Francisco amounted to a reduction in the contract price of 1.3%.

Thus it can be seen that a contractor certainly has reason to avoid extrapolation. When only a small portion of a contract is being inspected the number of observed defects will also be small. Therefore, deductions taken for observed defects will be minor. Where the contractor can also expect to rework the item, there is little financial incentive to do it right the first time. However, if deductions are extrapolated, the final percent deducted will more closely reflect actual performance. The impact of this is shown graphically in the next section.

6. Effect on Performance

It is impossible to definitively state what factors influenced performance at each activity. One fact is that both contractors quickly learned to avoid extrapolation. The ten incidences of extrapolation at PWC Great lakes occurred in the first eleven months of the contract. Seven of those extrapolations were assessed for unsatisfactory performance in response to routine calls. Response to routine calls was the only area where Great Lakes experienced any problems.

Figure 5.6 plots contractor performance in response to routine calls at Great Lakes, along with the corresponding percent of contract payment each month. Extrapolation took place from June to October; and then again in December and February. It should be noted that in these months payment actually fell below the performance level. This is an undesirable state of affairs from NAVFAC's point of view, and occurred because deductions were taken for validated customer complaints in addition to the extrapolation. Due to the high CPL of 97%, the contractor was forced to perform within a relatively narrow band to avoid extrapolation. In February of 1985, for example, the CND was exceeded even though performance was at 95.4%. The last year of the contract has seen steady high performance in all service areas.

Performance at PWC San Francisco was erratic in all service categories. Figure 5.7 plots performance in

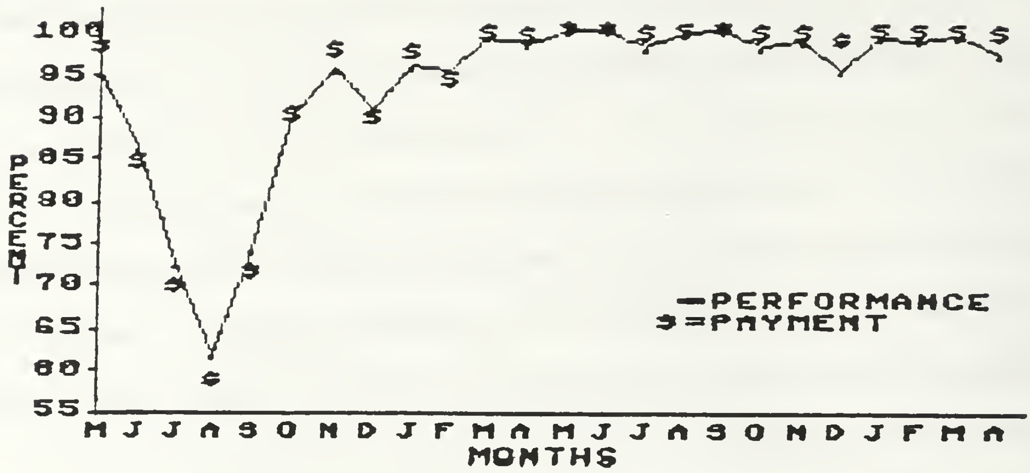


Figure 5.6 Performance/Payment Comparison at PWC Great Lakes

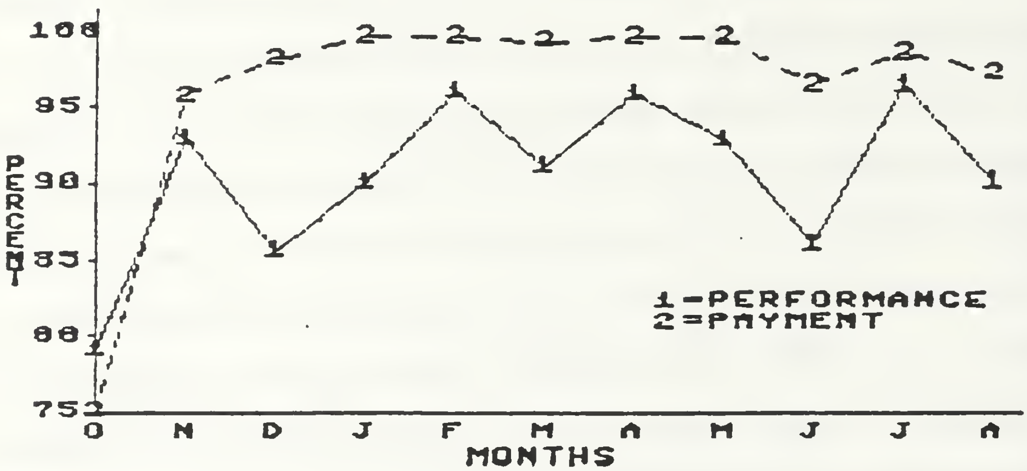


Figure 5.7 Performance/Payment Comparison at PWC San Francisco

exterior maintenance, along with the corresponding percent of contract payment each month. Except for the extrapolation which occurred in the first month, performance in exterior maintenance typified the other two work categories. The potential of extrapolated deductions is most evident from this plot. It can be seen that where extrapolation took place, payment was well below performance. Again, this is a result of taking deductions outside the sample. However, due to the low CPL of 90%, the contractor was able to perform at levels as low as 85.7% without exceeding the CND. Because the level of inspection was low, large gaps existed between payment and performance. In fact, the closer the contractor could get to the CND without reaching it, the greater would be his favorable gap between performance and payment. Thus, it appears that the contractor was able to manipulate his performance to maximize payment differential.

7. <u>Comparison with RSED V3.0</u>

I did a deduction analysis with the PWC San Francisco data assuming that RSED V3.0 had been in affect. The questionable assumption in such an analysis was that contractor performance remained the same. This is questionable because performance would have been judged unsatsifactory eight times vice once, resulting in more pressure through CDRs. In addition, the fact that payment would have

more closely matched performance would have provided additional incentive.

The level of deductions under RSED V3.0 would have been $3,766.00 per month. This represents 4.7% of the contract price and a monthly increase in total deductions over the field method of $2,696.00. This increased deduction level would have to be paid for with increased inspections. Monthly inspections required by RSED V3.0 would represent an 81% increase from 221 inspections to 401. At least one new inspector would have been required to cover this requirement. The extra deductions would pay for that new inspector only if performance did not increase!

Discrepancies between pay and performance will be minimal at all levels under RSED V3.0. Payment will normally be about 1% in excess of performance if this methodology is properly applied. This will eliminate any motivation for the contractor to underperform, as now exists at San Francisco. However, the fact that all deductions will be extrapolated removes a clear goal tied to the pocketbook. That "goal" appeared effective in ensuring contractor performance within a narrow band at PWC Great Lakes.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. GENERAL ISSUES

1. Need for Oversight

This study found that in a few areas, discrepancies existed between the RSED procedures implemented at the test activities and the intentions of NAVFAC. These discrepancies occurred because of either a lack of clear guidance or an omission on the part of the activity. Major examples indicating a lack of communication between NAVFAC and the activities are: (1) the failure of both activities to extrapolate when observed defects equaled the CND, (2) the taking of deductions in addition to extrapolation, and (3) different approaches planned for the extrapolation of liquidated damages.

Problems such as these must not only be anticipated in future guidance, but incorporated into sample working documents where possible. In addition, the potential for misunderstandings justifies an internal command assistance program. Evaluation of RSED plans at the EFD level would promote uniformity and provide assistance. This simple followup would help preclude the Air Force experience with GAO audits. Because of the small number of activities involved, effective oversight would not be difficult to

implement. When correct procedures became entrenched in the system, this special effort could be phased out.

2. Treatment of Sample Adjustment

The review of activity QA plans and discussion with contract administrators indicated that the potential for unnecessary sample adjustment was great. Current guidance does not clearly address the issue of sample size adjustment. This problem becomes even more critical under RSED V3.0 due to the monthly extrapolations and narrow sampling requirements. Lacking statistical backgrounds, contract administrators' actions are unpredictable. Worse than the expedient procedure at PWC San Francisco, would be to overcompensate.

The analysis of the effect that sample size had on confidence level suggests that original samples should provide adequate basis for contract action in all but the most extreme cases. A simple cutoff might be a minimum sample size of 50. Where the original sample is based on a good faith estimate and exceeds 50, no adjustment would be necessary. Specifying a minimum confidence level of 50% before adjustment was necessary would be another approach. However, that would require software support to speed the process and ensure against miscalculation.

3. Combining Homogeneous Populations

The benefits of random sampling increase exponentially with population. Due to the nature of service

contracting, strict homogeneity is almost never achieved within any population. Where two services have the same CPL and similar unity costs, the possibility of combining those populations should be examined. Inspection to different standards would not present a problem. This process would be similar to the combination of service calls into another category as was done at San Francisco. However, in that case no benefits were realized because three categories were still used. Candidates for combination should be studied and methods promulgated to make RSED more efficient.

4. <u>Surveillance Levels</u>

The wisdom of sampling at increased levels of inspection is questionable. Tightened inspection does not result in increased levels of extrapolation. Sample sizes required by tightened inspection (99% confidence) are significantly higher than normal sampling. It was done at PWC Great lakes through the use of overtime and reassignment. At PWC San Francisco, constrained resources prevented its use.

Where contractor performance has been poor and inspector resources are available, minimum levels of random sampling should be supplemented with planned sampling. This procedure makes use of inspector judgment to enhance the probability of identifying defects while maintaining extrapolation. More flexibility is gained because there is no need to obtain a "proper" sample at the higher level.

Future guidance should clearly document the procedures for mixing these two QA techniques and promote its use.

5. Performance/Payment Match

Under the field version, the mismatch between payment and performance increases with a lower CPL. While this mismatch provides a powerful incentive to avoid extrapolation, it appeared to result in planned nonconformance at PWC San Francisco. Deductions can only act as a motivator where payment closely follows performance.

Guidance specifications, when developed, should include minimum CPLs. This is especially true where the field version is in use, as inspection levels are a function of the CPL. Activities should be required to justify lower CPLs. This study indicates that a CPL of 90% for service calls is too low.

6. Computer Assistance

The complexity of RSED requires computer support over a range of operations. This support is necessary to both reduce the administrative burden and minimize the chance of error. Programs now exist which are close to satisfying this need. Full service programs should include: sample generation with flexible numbering, sample adjustment with decision routine, payment analysis, and sample history if appropriate for identifying planned samples.

Computer support should be a requirement for activities planning on implementing a RSED program. The high

payback of random sampling would justify this investment. Software issued by NAVFAC could also be designed to help ensure uniformity in the application of RSED.

B. RSED V3.0

The proposed method of taking extrapolated deductions is an improvement over the field version in that deductions and inspection requirements are not a function of the CPL. It provides a better match between payment and performance at lower CPL levels. The sample sizes required by RSED V3.0 are approximately equal to normal sampling at a CPL of 95% and reduced sampling at 97%. Thus, activities with a planned CPL of 90% or less would experience a significant increase in sample requirements.

Possible disadvantages associated with RSED V3.0 include:

(1) RSED places more emphasis on proper samples due to monthly extrapolation.

(2) There is no clear measure of good performance which provides financial incentive.

(3) Where contractor performance is consistently good, there is no reduced inspection level possible because of the need to extrapolate.

(4) Influence of customer complaints is diminished because they cannot be used to take deductions.

(5) The addition of a payment "adjustment" is one more complication added to the payment analysis. Rounding procedures must be clearly addressed.

The importance of these disadvantages was not studied.

I support NAVFAC's intentions to try RSED V3.0 because of the weakness of the field version in influencing performance at low CPL levels. This phenomenon was demonstrated at PWC San Francisco. However, results from the field will have to be analyzed before a definitive statement can be made. Interesting comparisons could be made by shifting PWC San Francisco and PWC Great Lakes to RSED V3.0 under the same contractor.

C. RECOMMENDATIONS FOR FUTURE STUDY

1. The impact of RSED V3.0 on contract price and performance.

2. Relationship between inspector aggressiveness and QA technique. For example, if an inspector knows that every defect identified will have ramifications beyond its own importance, will he be less likely to document borderline cases?

3. A cost/benefit study of RSED versus planned sampling.

4. A legal study which attempts to define the parameters within which NAVFAC must stay when designing a RSED program.

5. Identification of specific contractors which serve both the Navy and Air Force under their respective RSED programs. Compare payment and performance. Interview the contractor for his perspective.

APPENDIX A

USING MIL-STD-105D

The procedure contained in this appendix is taken in part from OFPP Pamphlet No. 4, "A Guide For Writing and Administering Performance Statements of Work For Service Contracts." The OFPP approach is equivalent to Air Force inspection procedures given in AFR 400-28. A sample size and corresponding accept/reject numbers are then determined for a hypothetical case, along with the associated producer/consumer risk.

SAMPLING PLAN

A. Deciding on the Acceptable Quality Level (AQL). The AQL is the highest number of defects per hundred, highest percent defective or highest number of defects that can be allowed for any service performance indicator. There are only a limited number of AQLs listed in MIL-STD-105D but, in virtually all cases, one will be close enough to control the contractor's level of service.

(1) The first step in designing a sampling plan under MIL-STD-105D is the selection of a realistic AQL. No service can be perfectly performed.

(2) Find the closest AQL from Figure 1 and use it to replace the original AQL on the Performance Requirement Summary. For example, the AQL for taxi service might have been 5 percent. This would be changed to 4 percent or 6.5 percent since 5 percent does not appear in the figure.

B. Determining the Lot Size. To determine the sample size, the lot size must be known. The lot is how often the contractor provides the service in a period of time.

(1) To determine the lot size, estimate the frequency of the service to be sampled, during the period it is to be sampled.

(2) In the case of workorders, the monthly lot size can be estimated from historical information on file.

C. Determining the Sample Size. Use Figure 2 to identify an appropriate sample size for a given lot size.

(1) Use the normal sample size column unless there is a limited number of QAEs or unless the cost of an inspection suggests the use of the medium or small sample size column.

(2) Use the medium or small sample size, if inspections for a particular service are lengthy or hinder the contractor's ability to provide service to customers.

D. Selecting the Rejection Level. Use MIL-STD-105D to identify the acceptance and rejection level for the sample size (see Figure 3). To use the figure, begin with the known values for the AQL and the sample size.

(1) Find the selected sample size (in the sample size column) and read across that line to the column for the selected AQL. At that point there will either be two numbers or an arrow pointing up or down.

Allowable Acceptable Quality Levels	
0.010 %	1.0 %
0.015 %	1.5 %
0.025 %	2.5 %
0.040 %	4.0 %
0.065 %	6.5 %
0.10 %	10. %
0.15 %	15. %
0.25 %	25. %
0.40 %	40. %
0.65 %	65. %

Figure 1. List of MIL-STD-105D Acceptable Quality Levels

Lot Size	Normal Sample Size	Medium Sample Size	Small Sample Size
2-8	2	2	2
9-15	3	2	2
16-25	5	3	3
26-50	8	5	5
51-90	13	5	5
91-150	20	8	8
151-280	32	13	13
281-500	50	20	13
501-1,200	80	32	20
1,201-3,200	125	50	32
3,201-10,000	200	80	32
10,001-35,000	315	125	50
35,001-150,000	500	200	80
150,001-500,000	800	315	80
500,000 and over	1250	500	125

Figure 2. Sample Sizes

Master Table for Normal Inspection – Single Sampling (Mil. Std. 105D, Table II-A)

Sample size code letter	Sample size	0.010 Ac Re	0.015 Ac Re	0.025 Ac Re	0.040 Ac Re	0.065 Ac Re	0.10 Ac Re	0.15 Ac Re	0.25 Ac Re	0.40 Ac Re	0.65 Ac Re	1.0 Ac Re	1.5 Ac Re	2.5 Ac Re	4.0 Ac Re	6.5 Ac Re	10 Ac Re	15 Ac Re	25 Ac Re	40 Ac Re	65 Ac Re	100 Ac Re	150 Ac Re	250 Ac Re	400 Ac Re	650 Ac Re	1000 Ac Re
		Acceptable Quality Levels (normal inspection)																									
A	2	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↓	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31
B	3	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45
C	5	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	↑
D	8	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	↑	↑
E	13	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	↑	↑	↑
F	20	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑
G	32	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑
H	50	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑
J	80	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑
K	125	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
L	200	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
M	315	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
N	500	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
P	800	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
Q	1250	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
R	2000	↑	↑	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑

↓ = Use first sampling plan below arrow. If sample size equals, or exceeds, lot or batch size, do 100 percent inspection.

↑ = Use first sampling plan above arrow.

Ac = Acceptance number.

Re = Rejection number.

Figure 3. MIL-STD-105D Normal Sampling Table

(2) If there is an arrow, follow the direction of the arrow until it leads to a pair of numbers. Of the two numbers at the intersection or at the end of the arrow, the number on the left (Ac or accept) indicates the maximum number of defects which can occur in a sample and still permit the total group or lot to be judged acceptable.

(3) When there is no accept or reject number for a given sample size and AQL, following the arrow will also cause a change in sample size. For example, with an AQL of 1.5 and a sample size of 20, the sample size would become 32.

(4) The number on the right (Re or reject) indicates the minimum number of defects that occur in a sample which causes the total group or lot to be judged unacceptable. For example, suppose the sample size is determined to be 32 and the AQL has been set at 6.5 defects per hundred. Find the number 32 in the sample size column and read across that line until the AQL column for 6.5 has been reached. The two numbers at that intersection are 5 and 6.

EXAMPLE CALCULATION

Given information:

1. Estimated number of services for month: 1000
2. AQL: 6.5 percent
3. Normal inspection desired

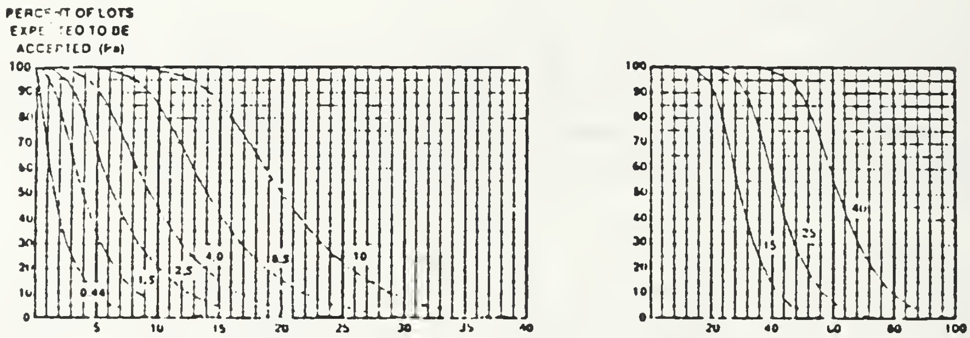
Determined from the tables:

1. Sample size: 80
2. Accept number: 10
3. Reject number: 11

It should be noted for this example that even though the activity has specified 6.5% defective as satisfactory performance, it will accept 10 defective work units out of a sample of 80!. This equates to 12.5% of the sample being defective.

From Figure 4 it can be seen that if the actual level of defects present were 8.0%, the probability of acceptance would be 95%. This equates to a producer (contractor) risk of 5%. At the same time, even if the actual level is as high as 11%, it will still be accepted 75% of the time. Thus consumer (government) risk at that level of performance is 75%. This represents a large bias in favor of the contractor.

CHART C-G - OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES



QUALITY OF SUBMITTED LOTS (p, in percent defective for AQL's ≤ 10; in defects per hundred units for AQL's > 10)

Note: Figures on curves are Acceptable Quality Levels (AQL's) for normal-tightened inspection.

TABLE C-G-TABULATED VALUES FOR OPERATING CHARACTERISTIC CURVES FOR NORMAL-TIGHTENED SINGLE SAMPLING SCHEMES

Pa	ACCEPTABLE QUALITY LEVELS														
	0.40	1.5	2.5	4.0	6.5	10	0.10	1.5	2.5	4.0	6.5	10	15	25	40
	p (percent defective)						p (defects per hundred units)								
99.0	0.031	0.470	1.38	2.66	5.85	9.71	0.031	0.463	1.36	2.57	5.55	8.06	14.8	23.3	39.3
95.0	0.156	1.09	2.47	4.24	6.08	12.7	0.156	1.08	2.42	4.13	7.78	12.1	18.9	28.6	46.0
90.0	0.306	1.55	3.12	5.17	8.23	14.2	0.306	1.54	3.08	5.07	8.97	13.9	21.0	31.3	49.3
75.0	0.733	2.48	4.39	6.89	11.1	16.7	0.736	2.47	4.37	6.84	11.1	15.4	24.8	35.8	54.8
50.0	1.60	3.92	9.37	9.41	14.0	20.1	1.51	3.85	9.42	9.50	14.1	20.2	29.5	41.9	62.0
25.0	3.05	6.00	9.26	12.9	17.8	24.5	3.11	8.11	9.50	13.3	18.3	25.3	35.7	49.4	70.9
10.0	5.00	9.52	12.3	16.8	22.0	[illegible]	5.13	8.79	13.3	17.7	23.3	31.2	42.8	57.4	80.2
5.0	6.43	10.4	15.2	19.4	25.0	32.3	6.71	10.8	16.1	20.8	26.8	35.2	47.2	62.9	86.4
1.0	10.0	14.6	20.4	25.0	31.0	38.5	10.6	15.6	22.3	27.9	34.6	43.6	56.9	73.5	99.0

Note: Binomial distribution used for percent defective computation, Poisson for defects per hundred units.

Figure 4. Operating Characteristic for Sample Size=32

APPENDIX B

MO-327 RANDOM SAMPLING PROCEDURES

This appendix is an excerpt from the current NAVFAC MO-327 entitled "Service Contracts: Specifications and Surveillance." It represents the NAVFAC guidance for random sampling prior to the field testing of extrapolated deductions. The MO-327 is presented here to illustrate the limited random sampling guidance available to activities planning to begin a random sampling program. Along with an explanation of random sampling, this appendix includes inspection tables and a procedure to generate random numbers.

When NAVFAC has finalized their procedure for implementing extrapolated deductions Navy-wide, the guidance will appear in a new MO-327.

RANDOM SAMPLING

1. GENERAL. Random sampling is a surveillance method based on statistical theory. The key element of random sampling is that each and every occurrence of work has an equal chance of being evaluated. In order to achieve the desired end results, knowledge of the Contractor's overall performance based on evaluation of only part of the work, surveillance by random sampling must be applied properly. Key elements of random sampling are:

a. Sample size is specified for a given population to achieve a predetermined level of statistical accuracy.

b. The sample of work occurrences selected for evaluation must be selected by a random process in which each occurrence has equal chance for selection.

c. Once an evaluation schedule has been established, it must be followed through the surveillance period (i.e., monthly schedules).

d. Surveillance data gathered by other methods (i.e., customer complaints and unscheduled inspections) can not be combined with data gathered by random sampling.

e. Assessment of the Contractor's overall performance, projected from the observed condition of the sample, will always have the potential to be in error. Statements as to overall performance should be stated as "The Contractor's overall defect rate is in excess of X %." (Where "X" equals the observed defect rate minus one half the AQL--ex. ODR (9.2%) - 1/2 AQL (10%) = 4.2%.)

2. MECHANICS OF RANDOM SAMPLING. Random sampling is a structured approach based on statistics to contract surveillance. As such, there is a set procedure in its application. The mechanics of applying random sampling are as follows.

3. POPULATION. The total number of work occurrences for a given function that are to be performed during the surveillance period must be known or accurately estimated. The Inventory of Service Worksheet is used to determine population size.

a. When work is scheduled, population size is easy to determine.

Example: Activity X has 80 dumpsters, 70 are emptied weekly and 10 are emptied twice a week. The

population, total number of work occurrences per month, is 360 (70 x 4) + (10 x 4 2).

b. When work is unscheduled, population size must be estimated.

Example: The number of service requests for the past six months were:

Jan	321
Feb	301
Mar	295
Apr	337
May	340
Jun	320
Total	1914

The average number of service calls per month has been 319 (1914/6). This would be the expected population for service calls for next month unless there is some known reason to expect a change.

4. SAMPLE SIZE. Sample size requirements are based on AQL, population size, and level of surveillance. Sample size tables are used to determine sample size. Tables for normal surveillance, reduced surveillance, and increased surveillance are attached.

a. Select the table with the desired level of surveillance (Tables I, II, or III).

b. Select the column with the required AQL (.05, .10, .15, .20, or .25).

c. Select the row that is closest to the population size, preferably the next largest entry.

d. The number indicated by the row and column selection is the sample size required for surveillance in one surveillance period.

(1) Daily surveillance requirements will be determined by dividing the required period's sample size by the number of days that surveillance is to be conducted.

(2) Weekly surveillance requirements will be determined by dividing the required sample size by the number of weeks in a period.

(3) When computing weekly or daily sample sizes, always round up to the next whole number (e.g., 45 monthly

samples required and 20 work days per month results in a daily sample size of 3 - (45/20) = 2.25 and rounded up results to 3).

5. <u>Sample Selection</u>. The final thing to be decided in sampling is how the sample will be drawn. The objective in the method is to insure that the sample is random (that is, that all services have an equal chance of being selected). To achieve random selection, use a random numbers table as explained in the following examples. (A random numbers table, Table IV, is attached). Most items will fall into one of these examples.

a. <u>Use of The Random Numbers Table</u>. The random numbers in Table IV are arranged in groups of two.

(1) To use the table, begin by picking at random a group of numbers on any page of the table. This is usually done by closing the eyes and pointing with a pencil or finger to some initial group.

(2) To identify additional random numbers, follow a pattern. Go along a given line to its end and then along the next line to its end and so on through the table until enough numbers have been selected or until the table ends.

(3) If the table ends and there are still more numbers to select, go back to the beginning of the table and continue using the same pattern. Use various patterns alternately, for example, use lines for one sample, use columns for the next sample, and use a diagonal pattern for the third sample.

b. <u>How To Use the Random Numbers Table To Identify a Random Sample of Consecutively Numbered Work orders</u>. Suppose one has to identify a random sample of 97 work orders for evaluation. (Sample size is based on a population of 319 using normal surveillance.) This can be done at the beginning of the month (before the work orders are written) or at the end of the month.

(1) If there are, or might be, 319 consecutively numbered work orders to select from, then one begins by listing the lowest work order number (known or projected). This cold be $001, or possibly 443, or any other sequentially assigned number. List the highest work order number (known or projected); in this case, it could be #319 or 762. For this example, use work orders numbered #443 to 762.

(a) Select 97 three digit numbers from Table IV using a consistent pattern.

(b) If random numbers selected are not between 443 and 762, discard the number outside the designated range and select a new number.

(2) For example, using the initial entry on Table IV we would select number 441. This number is too low. The next number, going down the column, is 343 again too low. The third number selected is 749. This number falls in the range of work order number (443-762) subject to inspection. So work order number 749 is selected to be inspected. The next work order number selected is 523.

(3) This process would be continued until three work orders are selected.

c. <u>How To Use The Random Numbers Table To Identify A Random Sample From A Group of Items</u>. If a number of items need to be sampled that are not consecutively numbered, the simplest solution is to list the identifiers, for all the items in a column, on a piece of lined paper.

(1) Next, number the lines consecutively, beginning with the number one. Now use the random number table to draw the sample from the line numbers. A selected line number leads to the identifier located on that line, and that identifier tells which item to sample. For example, if one chooses to sample a set of work orders with attached sales slips, one is not going to have to have a set of consecutively numbered work orders because not every work order has a sales slip attached.

(2) List the work orders with sales slips in a column, number each line in the column, and randomly select enough line numbers to make up the sample.

d. <u>How To Use The Random Numbers Table To Identify a Random Samples of Days</u>. Suppose one wants to identify four days in the month on which to sample something. The days of the month can be numbered 01 to 31 (or less, as appropriate).

(1) It is best to use a starting point different from the one used in the previous example. For the purpose of this example, it is being used again.

(2) One can move down the column from number to number until the first number between 01 and 31 is spotted. In this case, it is 22. Thus the 22nd day of the month is selected for sampling.

(3) Continuing in this fashion, one discovers that 11 is the next number selected. This number is disregarded.

Proceed in this manner until the four days for sampling have been identified. In our example, the 4 days selected would be 22, 11, 10 and 24.

(4) If it is not desirable to sample on weekends, discard those days selected that happen to fall on a weekend and continue that selection until the proper number of days has been selected.

e. How To use the Random Numbers Table To Identify a Random Sample of Times of Day. If one wants to select random times of day to sample a service such as taxi or bus service, use the 24 hour clock.

(1) If there are any constraints during each 24-hour period, take them into consideration. For example, suppose that base bus service operates between 0700 and 2300. Convert these times to minutes (e.g., 0700 = 0, 0410 = 130, 1215 = 315, etc.). Again, using Table IV and selecting three digit numbers and proceeding across the line from the initial number, one comes to 441, or 1421 hrs, as the first random time.

(2) The next random number is 343, or 1243 hrs. The number is good and so one schedules an observation for 1243 hrs.

(3) Proceed in this manner until the desired number of sample times have been identified.

f. How To Insure Variety in the Use of the Random Numbers Table. The use of variety in the random number table ensures that detectable patterns do not occur.

(1) Success in using the tables requires consistency but also variety. The above information should ensure that the tables are properly used and that the sample is randomly drawn.

g. Other Random Numbers Generating Methods. The use of a hand held calculator with a random number generating capability is an alternative to the use of random numbers table. Using this type of calculator the QAE would enter the minimum value and maximum value and numbers generated would always be within the desired range.

SAMPLE SIZE REQUIREMENTS FOR REDUCED SURVEILLANCE
(SURVEILLANCE LEVEL I)

POPULATION SIZE	AQL .05	.10	.15	.20	.25
50	31	21	16	11	9
75	34	25	17	13	10
100	44	27	18	13	10
125	49	28	19	14	10
150	52	30	20	14	10
175	55	30	20	14	10
200	57	31	20	14	11
225	59	32	20	14	11
250	60	32	21	14	11
275	61	32	21	15	11
300	63	33	21	15	11
325	64	33	21	15	11
350	64	33	21	15	11
375	65	33	21	15	11
400	66	34	21	15	11
425	67	34	21	15	11
450	67	34	21	15	11
475	68	34	21	15	11
500	68	34	21	15	11
550	69	34	22	15	11
600	70	34	22	15	11
650	70	35	22	15	11
700	71	35	22	15	11
750	71	35	22	15	11
800	72	35	22	15	11
850	72	35	22	15	11
900	73	35	22	15	11
950	73	35	22	15	11
1000	73	35	22	15	11
1100	74	35	22	15	11
1200	74	35	22	15	11
1300	74	36	22	15	11
1400	75	36	22	15	11
1500	75	36	22	15	11
1600	75	36	22	15	11
1700	75	36	22	15	11
1800	76	36	22	15	11
1900	76	36	22	15	11
2000	76	36	22	15	11
2500	76	36	22	15	11
3000	77	36	22	15	11
3500	77	36	22	15	11
4000	77	36	22	15	11
4500	77	36	22	15	11
5000	78	36	22	15	11
6000	78	36	22	15	11
7000	78	36	22	15	11
8000	78	36	22	15	11
9000	78	36	22	15	11
10000	78	36	22	15	11

SAMPLE SIZE REQUIREMENTS FOR NORMAL SURVEILLANCE
(SURVEILLANCE LEVEL II)

POPULATION SIZE	AQL .05	.10	.15	.20	.25
50	43	37	32	27	23
75	60	49	40	32	27
100	76	58	46	37	29
125	89	66	51	40	31
150	101	72	54	42	32
175	111	78	57	43	33
200	121	82	60	45	34
225	129	86	62	46	35
250	137	89	63	47	35
275	144	92	65	48	36
300	151	95	66	48	36
325	157	97	67	49	37
350	162	99	68	49	37
375	167	101	69	50	37
400	172	103	70	50	37
425	176	105	71	51	38
450	181	106	71	51	38
475	184	107	72	51	38
500	188	109	72	52	38
550	195	111	73	52	38
600	201	113	74	52	39
650	206	114	75	53	39
700	211	116	75	53	39
750	215	117	76	53	39
800	219	118	76	54	39
850	222	119	77	54	39
900	226	120	77	54	39
950	229	121	78	54	39
1000	231	122	78	54	39
1100	236	123	78	55	40
1200	241	124	79	55	40
1300	244	125	79	55	40
1400	248	126	80	55	40
1500	251	127	80	55	40
1600	253	128	80	55	40
1700	256	128	80	55	40
1800	258	129	81	56	40
1900	260	129	81	56	40
2000	262	130	81	56	40
2500	269	131	82	56	40
3000	274	132	82	56	41
3500	277	133	82	56	41
4000	280	134	83	57	41
4500	282	134	83	57	41
5000	284	135	83	57	41
6000	287	135	83	57	41
7000	289	136	83	57	41
8000	290	136	84	57	41
9000	291	136	84	57	41
10000	292	137	84	57	41

SAMPLE SIZE REQUIREMENTS FOR INCREASED SURVEILLANCE
(SURVEILLANCE LEVEL III)

POPULATION SIZE	AQL .05	.10	.15	.20	.25
50	47	43	39	35	31
75	67	59	52	46	39
100	86	74	63	54	45
125	104	87	72	60	50
150	121	98	80	65	53
175	136	108	86	69	56
200	151	116	92	73	58
225	164	124	97	76	60
250	177	132	101	79	62
275	189	138	105	81	63
300	201	144	108	83	64
325	211	150	111	85	65
350	222	155	114	86	66
375	231	159	116	88	67
400	241	164	119	89	68
425	249	168	121	90	69
450	258	172	123	91	69
475	266	175	124	92	70
500	273	178	126	93	70
550	288	184	129	95	71
600	301	189	132	96	72
650	313	194	134	97	73
700	324	198	136	98	73
750	334	202	138	99	74
800	344	206	139	100	74
850	352	209	141	101	75
900	361	212	142	101	75
950	368	214	143	102	75
1000	376	217	144	103	76
1100	389	221	146	103	76
1200	401	225	148	104	77
1300	411	228	149	105	77
1400	421	231	150	106	77
1500	429	234	151	106	77
1600	437	236	152	107	78
1700	444	238	153	107	78
1800	451	240	154	107	78
1900	457	241	155	108	78
2000	462	243	155	108	78
2500	485	249	158	109	79
3000	501	253	159	110	80
3500	513	256	161	111	80
4000	523	259	161	111	80
4500	530	260	162	111	80
5000	537	262	163	112	80
6000	546	264	164	112	81
7000	554	266	164	112	81
8000	559	267	165	113	81
9000	563	268	165	113	81
10000	567	269	165	113	81

SHORT TABLE OF RANDOM NUMBERS

44	19	15	32	63	55	87	77	33	29	45	00	31
34	39	80	62	24	33	81	67	28	11	34	79	26
74	97	80	30	65	07	71	30	01	84	47	45	89
22	14	61	60	86	38	33	71	13	33	72	08	16
40	03	96	40	03	47	24	60	09	21	21	18	00
52	33	76	44	56	15	47	75	78	73	78	19	87
37	59	20	40	93	17	82	24	19	90	80	87	32
11	02	55	57	48	84	74	36	22	67	19	20	15
10	33	79	26	34	54	71	33	89	74	68	48	23
67	59	28	25	47	89	11	65	65	20	42	23	96
98	50	75	20	09	18	54	34	68	02	54	87	23
24	43	23	72	80	64	34	27	23	46	15	36	10
39	91	63	18	38	27	10	78	88	84	42	32	00
74	62	19	67	54	18	28	92	33	69	98	96	74
91	03	35	60	81	16	61	97	25	14	78	21	22
42	57	66	76	72	91	03	63	48	46	44	01	33
96	36	63	06	15	03	72	38	01	58	25	37	66
92	70	96	70	89	80	87	14	25	49	25	94	62
91	08	88	53	52	13	04	82	23	00	26	36	47
68	85	97	74	47	53	90	05	90	34	87	48	25
59	54	13	09	13	80	42	29	63	03	24	64	12
39	18	32	69	33	46	58	19	34	03	59	28	97
67	43	31	09	12	60	19	57	63	78	11	80	10
61	75	37	19	56	90	75	39	03	56	49	92	72
78	10	91	11	00	63	19	63	74	58	69	03	51
93	23	71	58	09	78	08	03	07	71	79	32	25
37	55	48	82	63	89	92	59	14	72	19	17	22
62	13	11	71	17	23	29	25	13	85	33	35	07
29	89	97	47	03	13	20	86	22	45	59	98	64
16	94	85	82	89	07	17	30	29	89	89	80	98
04	93	10	59	75	12	98	84	60	93	68	16	87
95	71	43	68	97	18	85	17	13	08	00	50	77
86	05	39	14	35	48	68	18	36	57	09	62	40
59	30	60	10	41	31	00	69	63	77	01	89	94
05	45	35	40	54	03	98	96	76	27	77	94	80
71	85	17	74	66	27	85	19	55	56	51	36	48
80	20	32	80	98	00	40	92	57	51	52	83	14
13	50	78	02	73	39	66	82	01	28	67	51	75
67	92	65	41	45	36	77	96	46	21	14	39	56
72	56	73	44	26	04	62	81	15	35	79	26	99
28	86	85	64	94	11	58	78	45	36	34	45	91
69	57	40	80	44	94	60	82	94	93	98	01	48
71	20	03	30	79	25	74	17	78	34	54	45	04
89	98	55	98	22	45	12	49	82	71	57	33	28
58	74	82	81	14	02	01	05	77	94	65	57	70
50	54	73	81	91	07	81	26	25	45	49	61	22
49	33	72	90	10	20	65	28	44	63	95	86	75
11	85	01	43	65	02	85	69	56	88	34	29	64
34	22	46	41	84	74	27	02	57	77	47	93	72
42	64	64	58	22	75	81	74	91	48	46	18	34
84	05	72	90	44	27	78	22	07	62	17	35	34
23	39	94	00	80	55	31	63	27	91	70	74	13
04	90	51	27	61	34	63	87	44	13	50	56	48

51	29	48	30	93	45	66	29	05	86	52	85	40
73	73	57	68	36	33	91	06	98	47	48	02	62
03	42	05	32	55	02	74	59	84	24	49	79	17
23	75	83	42	00	92	53	37	13	75	34	89	56
73	23	39	07	17	49	18	81	35	52	95	70	05
73	11	17	41	64	20	30	89	87	64	37	93	36
96	35	05	43	36	98	29	97	93	87	08	30	92
98	63	21	59	69	76	02	62	31	62	47	60	34
97	92	00	04	94	50	05	75	82	70	80	35	35
72	11	68	25	08	95	31	79	11	79	54	05	25
47	26	37	80	39	19	06	41	02	00	53	62	28
80	59	55	05	02	16	13	17	54	48	56	19	56
41	29	28	76	49	74	39	50	78	26	15	41	39
48	75	64	69	61	06	38	44	04	08	84	80	07
44	76	51	52	41	59	01	11	05	45	11	43	15
60	40	31	84	59	43	28	10	01	65	62	07	79
83	05	59	61	31	02	65	47	47	70	39	74	17
30	22	65	97	15	70	04	89	81	78	54	84	87
83	42	95	27	52	87	47	12	52	54	62	43	23
13	38	60	36	53	56	77	06	69	03	89	91	24
19	61	04	40	33	12	06	78	91	97	88	95	51
90	20	03	64	96	60	48	01	95	44	84	69	25
68	57	92	57	11	84	44	01	33	66	53	89	64
94	81	55	87	73	81	58	56	42	36	25	36	53
02	49	14	34	03	52	09	20	60	11	50	46	56
58	45	88	72	50	46	11	50	46	92	45	25	97
21	48	22	23	08	32	28	87	08	74	79	91	08
27	12	43	32	03	60	19	02	70	88	72	33	38
88	20	60	86	08	64	50	44	34	54	24	85	20
85	77	32	92	32	44	40	47	10	38	22	52	42
29	96	55	31	99	73	23	40	07	64	54	44	99
21	66	33	97	47	58	42	44	88	09	28	58	06
36	70	15	74	43	62	69	82	30	77	28	77	57
28	22	25	94	80	62	95	48	98	23	86	38	51
10	68	36	87	81	16	77	30	19	36	50	57	69
60	77	69	60	74	22	05	77	17	77	42	59	75
78	64	99	37	03	18	03	36	69	50	59	15	09
25	79	39	42	84	18	70	39	42	48	56	84	31
59	18	70	41	74	60	88	41	20	00	15	59	93
51	60	65	65	63	78	69	24	41	65	86	10	34
10	32	00	93	35	48	15	70	11	77	83	01	34
82	91	04	02	95	63	75	74	69	69	61	34	31
92	13	05	57	23	06	26	23	08	66	16	11	75
28	81	37	78	16	05	57	12	46	22	90	97	78
67	39	23	71	15	08	82	64	87	29	01	20	46
72	05	42	67	98	41	67	44	28	71	45	08	19
47	76	05	83	03	84	32	62	83	27	48	83	09
19	84	60	46	18	41	23	74	73	51	72	90	40
52	95	32	80	64	75	91	98	09	40	64	89	29
99	46	79	86	53	77	78	06	62	37	48	82	71
00	78	45	13	23	32	01	09	46	36	43	66	37
15	35	20	60	97	48	21	41	84	22	72	77	99
81	83	67	91	44	83	43	25	56	33	23	80	99
53	27	86	50	76	93	86	35	68	45	37	83	47

APPENDIX C

SAMPLING TABLES USED IN THE FIELD TEST

This appendix contains tables reproduced from those utilized at each activity. The first group of tables were used by PWC San Francisco at the CPL = 90% level. Great Lakes used the second group of tables at the CPL = 97% level. Both groups of tables were generated from the same formula. The tables provide graphic illustration of the effect that the CPL, surveillance level and population have on the sample size and CND.

CND/SS TABLE

CRITICAL NUMBER OF DEFECTIVES (CND)/SAMPLE SIZE (SS)

Reduced Surveillance (Page 1 of 2)

UNITS OF WORK POPULATION SIZE	CRITICAL PERFORMANCE LEVEL (CPL) 95% CND/SS	90% CND/SS	85% CND/SS	80% CND/SS	75% CND/SS
50	3/36	5/27	6/21	6/17	6/14
75	4/47	6/33	6/25	7/19	7/26
100	5/56	6/37	7/27	7/21	7/16
125	6/62	7/40	7/29	7/22	7/17
150	6/68	7/42	8/30	7/22	7/17
175	6/73	8/44	8/31	8/23	8/18
200	7/77	6/46	8/31	8/23	8/18
225	7/80	8/47	8/32	8/24	8/18
250	7/83	8/48	8/32	8/24	8/18
275	7/86	8/49	8/33	8/24	8/18
300	8/88	8/49	8/33	8/24	8/19
325	8/90	9/50	8/33	8/24	8/19
350	8/92	9/51	9/34	8/24	8/19
375	8/94	9/51	9/34	8/25	8/19
400	8/95	9/52	9/34	8/25	8/19
425	8/97	9/52	9/34	8/25	8/19
450	8/93	9/52	9/34	8/25	8/19
475	9/99	9/53	9/35	8/25	8/19
500	9/100	9/53	9/35	8/25	8/19
550	9/102	9/53	9/35	8/25	8/19
600	9/103	9/54	9/35	8/25	8/19
650	9/105	9/54	9/35	8/25	8/19
700	9/106	9/55	9/35	8/25	8/19
750	9/107	9/55	9/35	8/25	8/19
800	9/108	9/55	9/36	8/25	8/19
850	9/109	9/55	9/36	9/26	8/19
900	9/110	10/56	9/36	9/26	8/19
950	9/110	10/56	9/36	9/26	8/19
1000	10/111	10/56	9/36	9/26	8/19
1100	10/112	10/56	9/36	9/26	8/19
1200	10/113	10/56	9/36	9/26	8/19
1300	10/114	10/57	9/36	9/26	8/19
1400	10/115	10/57	9/36	9/26	8/19
1500	10/115	10/57	9/36	9/26	8/19
1600	10/116	10/57	9/36	9/26	8/19
1700	10/116	10/57	9/36	9/26	8/19
1800	10/117	10/57	9/36	9/26	8/20
1900	10/117	10/57	9/37	9/26	8/20
2000	10/118	10/57	9/37	9/26	8/20
2500	10/119	10/58	9/37	9/26	8/20

CND/SS TABLE

CRITICAL NUMBER OF DEFECTIVES (CND)/SAMPLE SIZE (SS)

Reduced Surveillance (Page 2 of 2)

UNITS OF WORK POPULATION SIZE	CRITICAL PERFORMANCE LEVEL (CPL)				
	95%	90%	85%	80%	75%
	CND/SS	CND/SS	CND/SS	CND/SS	CND/SS
3000	10/120	10/58	9/37	9/26	8/20
3500	10/121	10/58	9/37	9/26	8/20
4000	10/121	10/58	9/37	9/26	8/20
4500	10/122	10/58	9/37	9/26	8/20
5000	10/122	10/58	9/37	9/26	8/20
6000	10/122	10/59	9/37	9/26	8/20
7000	11/123	10/59	9/37	9/26	8/20
8000	11/123	10/59	9/37	9/26	8/20
9000	11/123	10/59	9/37	9/26	8/20
10000	11/123	10/59	9/37	9/26	8/20
20000	11/124	10/59	9/37	9/26	8/20
30000	11/124	10/59	9/37	9/26	8/20
40000	11/125	10/59	9/37	9/26	8/20
50000	11/125	10/59	9/37	9/26	8/20
60000	11/125	10/59	9/37	9/26	8/20
70000	11/125	10/59	9/37	9/26	8/20
80000	11/125	10/59	9/37	9/26	8/20
90000	11/125	10/59	9/37	9/26	8/20
100000	11/125	10/59	9/37	9/26	8/20
250000	11/125	10/59	9/37	9/26	8/20
500000	11/125	10/59	9/37	9/26	8/20

CND/SS TABLE

CRITICAL NUMBER OF DEFECTIVES (CND)/SAMPLE SIZE (SS)

Normal Surveillance (Page 1 of 2)

UNITS OF WORK POPULATION SIZE	CRITICAL PERFORMANCE LEVEL (CPL)				
	95%	90%	85%	80%	75%
	CND/SS	CND/SS	CND/SS	CND/SS	CND/SS
50	4/40	6/33	7/28	8/23	8/20
75	5/55	7/42	9/34	9/27	9/23
100	6/67	8/49	10/38	10/30	10/25
125	7/78	9/55	10/41	11/32	11/26
150	8/87	10/59	11/44	11/34	11/27
175	8/95	11/63	11/45	12/35	11/27
200	9/101	11/66	12/47	12/36	11/28
225	9/107	11/68	12/48	12/36	11/28
250	10/113	12/70	12/49	12/37	12/49
275	10/118	12/72	12/50	12/37	12/29
300	10/122	12/74	13/51	13/38	12/29
325	11/126	13/75	13/52	13/38	12/30
350	11/130	13/76	13/52	13/39	12/30
375	11/133	13/77	13/53	13/39	12/30
400	12/136	13/78	13/53	13/39	12/30
425	12/139	13/79	13/54	13/39	12/30
450	12/141	13/80	13/54	13/39	12/30
475	12/144	14/81	13/54	13/40	12/30
500	12/146	14/82	14/55	13/40	12/30
550	13/150	14/83	14/55	13/40	13/31
600	13/153	14/84	14/56	13/40	13/31
650	13/156	14/85	14/56	13/41	13/31
700	13/159	14/86	14/56	13/41	13/31
750	14/161	14/85	14/57	13/41	13/31
800	14/164	15/87	14/57	13/41	13/31
850	14/166	15/87	14/57	13/41	13/31
900	14/167	15/88	14/57	13/41	13/31
950	14/169	15/88	14/58	13/41	13/31
1000	14/172	15/89	14/58	13/41	13/31
1100	15/173	15/89	14/58	14/42	13/32
1200	15/176	15/90	14/58	14/42	13/32
1300	15/178	15/91	15/59	14/42	13/32
1400	15/179	15/91	15/59	14/42	13/32
1500	15/181	15/91	15/59	14/42	13/32
1600	15/182	15/92	15/59	14/42	13/32
1700	15/183	15/92	15/59	14/42	13/32
1800	16/185	15/92	15/59	14/42	13/32
1900	16/186	15/93	15/59	14/42	13/32
2000	16/186	15/93	15/60	14/42	13/32
2500	15/190	16/94	15/60	14/43	13/32

CND/SS TABLE

CRITICAL NUMBER OF DEFECTIVES (CND)/SAMPLE SIZE (SS)

Normal Surveillance (Page 2 of 2)

UNITS OF WORK POPULATION SIZE	CRITICAL PERFORMANCE LEVEL (CPL)				
	95%	90%	85%	80%	75%
	CND/SS	CND/SS	CND/SS	CND/SS	CND/SS
3000	16/192	16/94	15/60	14/43	13/32
3500	16/194	16/95	15/60	14/43	13/32
4000	16/195	16/95	15/60	14/43	13/32
4500	17/197	16/95	15/61	14/43	13/32
5000	17/198	16/96	15/61	14/43	13/32
6000	17/199	16/96	15/61	14/43	13/32
7000	17/200	16/96	15/61	14/43	13/32
8000	17/201	16/96	15/61	14/43	13/32
9000	17/201	16/96	15/61	14/43	13/32
10000	17/202	16/96	15/61	14/43	13/32
20000	17/204	16/97	15/61	14/43	13/32
30000	17/204	16/97	15/61	14/43	13/32
40000	17/205	16/97	15/61	14/43	13/32
50000	17/205	16/97	15/61	14/43	13/32
60000	17/205	16/97	15/61	14/43	13/32
70000	17/205	16/97	15/61	14/43	13/32
80000	17/205	16/97	15/61	14/43	13/32
90000	17/205	16/97	15/61	14/43	13/32
100000	17/205	16/97	15/61	14/43	13/32
250000	17/205	16/97	15/61	14/43	13/32
500000	17/206	16/97	15/61	14/43	13/32

CND/SS TABLE

CRITICAL NUMBER OF DEFECTIVES (CND)/SAMPLE SIZE (SS)

Tightened Surveillance (Page 1 of 2)

UNITS OF WORK POPULATION SIZE	CRITICAL PERFORMANCE LEVEL (CPL)				
	95%	90%	85%	80%	75%
	CND/SS	CND/SS	CND/SS	CND/SS	CND/SS
50	4/45	7/40	9/36	11/32	11/28
75	6/63	9/54	12/47	13/40	14/35
100	7/80	11/66	24/55	15/46	16/39
125	8/95	13/76	15/62	17/51	17/43
150	9/110	14/85	17/68	18/55	18/43
175	10/123	15/92	18/72	19/56	19/47
200	11/135	16/99	19/76	20/60	20/49
225	12/145	17/104	19/79	20/63	20/50
250	13/156	18/110	20/82	21/64	21/52
275	14/165	19/114	21/85	21/65	21/53
300	15/174	20/118	21/87	22/67	21/53
325	15/182	20/122	22/89	22/68	22/54
350	16/189	21/125	22/91	22/69	22/55
375	16/196	21/128	23/92	23/70	22/55
400	17/203	22/131	23/94	23/70	22/56
425	18/209	22/134	23/95	23/72	22/56
450	18/215	22/136	24/96	24/73	23/57
475	18/220	23/133	24/98	24/73	23/57
500	19/226	23/140	24/99	24/74	23/58
550	20/235	24/144	24/100	24/75	23/58
600	20/244	24/147	25/102	25/76	24/59
650	21/252	25/150	25/103	25/76	24/59
700	22/259	25/152	25/104	25/77	24/59
750	22/266	25/155	26/105	25/78	24/60
800	23/272	26/157	26/106	25/78	24/60
850	23/277	26/159	26/107	25/79	24/60
900	23/282	26/159	26/107	25/79	24/60
950	24/287	27/162	27/109	26/79	24/61
1000	24/292	27/163	27/109	26/80	24/61
1100	25/299	27/166	27/110	26/80	24/61
1200	25/306	28/168	27/111	26/81	25/62
1300	26/313	28/170	27/112	26/81	25/62
1400	26/318	28/171	28/113	26/82	25/62
1500	27/323	28/173	28/113	26/82	25/62
1600	27/327	29/174	28/114	26/82	25/62
1700	27/331	29/175	28/114	26/82	25/63
1800	28/335	29/176	28/115	27/83	25/63
1900	28/335	29/177	28/115	27/83	25/63
2000	28/341	29/178	28/116	27/83	25/63
2500	29/353	30/181	29/117	27/84	25/63

CND/SS TABLE

CRITICAL NUMBER OF DEFECTIVES (CND)/SAMPLE SIZE (SS)

Tightened Surveillance (Page 2 of 2)

UNITS OF WORK POPULATION SIZE	CRITICAL PERFORMANCE LEVEL (CPL)				
	95%	90%	85%	80%	75%
	CND/SS	CND/SS	CND/SS	CND/SS	CND/SS
3000	30/362	30/183	29/118	27/84	25/64
3500	30/368	30/185	29/119	27/85	25/64
4000	31/373	30/186	29/119	27/85	26/64
4500	31/377	31/187	29/119	27/85	26/64
5000	31/380	31/188	29/120	27/85	26/64
6000	31/385	31/189	29/120	27/85	26/64
7000	31/389	31/190	29/121	28/86	26/64
8000	31/391	31/190	29/121	28/86	26/64
9000	31/394	31/191	30/121	28/86	26/65
10000	31/395	31/191	30/121	28/86	26/65
20000	31/403	31/193	30/122	28/86	26/65
30000	31/406	31/194	30/122	28/86	26/65
40000	31/407	31/194	30/122	28/86	26/65
50000	31/408	31/194	30/122	28/86	26/65
60000	31/409	31/194	30/122	28/87	26/65
70000	31/409	31/194	30/123	28/87	26/65
80000	31/409	31/194	30/123	28/87	26/65
90000	31/410	31/195	30/123	28/87	26/65
100000	31/410	31/195	30/123	28/87	26/65
250000	31/411	31/195	30/123	28/87	26/65
500000	31/411	31/195	30/123	28/87	26/65

CND/SS TABLE

REDUCED SURVEILLANCE

N	99%	98%	97%	96%	95%
50	1 / 46	2 / 43	2 / 40	3 / 38	3 / 36
75	2 / 67	2 / 61	3 / 55	4 / 51	4 / 47
100	2 / 87	3 / 76	4 / 68	4 / 61	5 / 56
125	2 / 105	3 / 90	4 / 79	5 / 70	6 / 62
150	2 / 122	4 / 102	5 / 88	6 / 77	6 / 68
175	3 / 138	4 / 113	5 / 96	6 / 83	6 / 73
200	3 / 153	5 / 123	6 / 103	6 / 88	7 / 77
225	3 / 167	5 / 132	6 / 109	7 / 93	7 / 80
250	3 / 181	5 / 141	6 / 115	7 / 97	7 / 83
275	4 / 193	5 / 148	6 / 120	7 / 100	7 / 86
300	4 / 205	6 / 155	7 / 124	7 / 103	8 / 88
325	4 / 217	6 / 162	7 / 129	7 / 106	8 / 90
350	4 / 228	6 / 168	7 / 132	8 / 109	8 / 92
375	4 / 238	6 / 173	7 / 136	8 / 111	8 / 94
400	5 / 248	6 / 178	7 / 139	8 / 113	8 / 95
425	5 / 257	6 / 183	7 / 142	8 / 115	8 / 97
450	5 / 266	7 / 188	8 / 144	8 / 117	8 / 98
475	5 / 275	7 / 192	8 / 147	8 / 118	9 / 99
500	5 / 283	7 / 196	8 / 149	8 / 120	9 / 100
550	5 / 298	7 / 203	8 / 153	9 / 123	9 / 102
600	6 / 312	7 / 210	8 / 157	9 / 125	9 / 103
650	6 / 325	8 / 215	8 / 160	9 / 127	9 / 105
700	6 / 337	8 / 221	8 / 163	9 / 129	9 / 106
750	6 / 348	8 / 225	9 / 166	9 / 130	9 / 107
800	6 / 359	8 / 230	9 / 168	9 / 132	9 / 108
850	7 / 369	8 / 234	9 / 170	9 / 133	9 / 109
900	7 / 378	8 / 237	9 / 172	9 / 134	9 / 110
950	7 / 386	8 / 241	9 / 174	9 / 135	9 / 110
1000	7 / 394	8 / 244	9 / 175	9 / 136	10 / 111
1100	7 / 409	9 / 249	9 / 178	9 / 138	10 / 112
1200	7 / 422	9 / 254	9 / 181	10 / 139	10 / 113
1300	8 / 434	9 / 258	9 / 183	10 / 141	10 / 114
1400	8 / 444	9 / 262	10 / 185	10 / 142	10 / 115
1500	8 / 454	9 / 265	10 / 186	10 / 143	10 / 115
1600	8 / 463	9 / 268	10 / 188	10 / 144	10 / 116
1700	8 / 471	9 / 271	10 / 189	10 / 144	10 / 116
1800	8 / 478	9 / 273	10 / 190	10 / 145	10 / 117
1900	8 / 485	9 / 275	10 / 191	10 / 146	10 / 117
2000	9 / 491	10 / 277	10 / 192	10 / 146	10 / 118
2500	9 / 516	10 / 285	10 / 196	10 / 148	10 / 119
3000	9 / 533	10 / 291	10 / 198	10 / 150	10 / 120
3500	9 / 549	10 / 295	10 / 200	10 / 151	10 / 121
4000	10 / 560	10 / 298	10 / 202	10 / 152	10 / 121

CND/SS TABLE

NORMAL SURVEILLANCE

N	99%	98%	97%	96%	95%
50	1 / 48	2 / 46	3 / 44	3 / 42	4 / 40
75	2 / 70	3 / 66	4 / 62	4 / 58	5 / 55
100	2 / 91	3 / 84	4 / 78	5 / 72	6 / 67
125	2 / 112	4 / 101	5 / 92	6 / 84	7 / 78
150	3 / 132	4 / 117	6 / 105	7 / 95	8 / 87
175	3 / 150	5 / 132	6 / 117	7 / 105	8 / 95
200	3 / 169	5 / 145	7 / 127	8 / 113	9 / 101
225	4 / 186	6 / 158	7 / 137	8 / 121	9 / 107
250	4 / 203	6 / 170	8 / 146	9 / 127	10 / 113
275	4 / 219	6 / 181	8 / 154	9 / 134	10 / 118
300	4 / 234	7 / 192	8 / 162	10 / 139	10 / 122
325	5 / 249	7 / 202	9 / 169	10 / 144	11 / 126
350	5 / 264	7 / 211	9 / 175	10 / 149	11 / 130
375	5 / 278	8 / 220	9 / 181	10 / 153	11 / 133
400	5 / 291	8 / 228	10 / 187	11 / 157	12 / 136
425	5 / 304	8 / 236	10 / 192	11 / 161	12 / 139
450	6 / 317	8 / 243	10 / 197	11 / 165	12 / 141
475	6 / 329	9 / 251	10 / 202	11 / 168	12 / 144
500	6 / 341	9 / 257	11 / 206	12 / 171	12 / 146
550	6 / 363	9 / 270	11 / 214	12 / 176	13 / 150
600	7 / 385	10 / 282	11 / 221	12 / 181	13 / 153
650	7 / 405	10 / 292	12 / 227	13 / 186	13 / 156
700	7 / 423	10 / 302	12 / 233	13 / 189	13 / 159
750	8 / 441	11 / 311	12 / 239	13 / 193	14 / 161
800	8 / 458	11 / 319	12 / 243	13 / 196	14 / 164
850	8 / 474	11 / 327	13 / 248	13 / 199	14 / 166
900	9 / 489	11 / 334	13 / 252	14 / 202	14 / 167
950	9 / 504	12 / 340	13 / 256	14 / 204	14 / 169
1000	9 / 517	12 / 347	13 / 259	14 / 206	14 / 171
1100	9 / 543	12 / 358	14 / 266	14 / 210	15 / 173
1200	10 / 566	13 / 368	14 / 271	14 / 214	15 / 176
1300	10 / 587	13 / 377	14 / 276	15 / 217	15 / 178
1400	10 / 607	13 / 385	14 / 280	15 / 219	15 / 179
1500	11 / 625	13 / 392	14 / 284	15 / 221	15 / 181
1600	11 / 642	14 / 398	15 / 287	15 / 223	15 / 182
1700	11 / 657	14 / 404	15 / 290	15 / 225	15 / 183
1800	12 / 672	14 / 410	15 / 293	15 / 227	16 / 185
1900	12 / 685	14 / 415	15 / 296	15 / 229	16 / 186
2000	12 / 698	14 / 419	15 / 298	15 / 230	16 / 186
2500	13 / 750	15 / 438	16 / 307	16 / 235	16 / 190
3000	13 / 790	15 / 451	16 / 313	16 / 239	16 / 192
3500	14 / 820	16 / 461	16 / 318	16 / 242	16 / 194
4000	14 / 845	16 / 468	16 / 322	16 / 244	16 / 196

CND/SS TABLE

TIGHT SURVEILLANCE

N	99%	98%	97%	96%	95%
50	1 / 49	2 / 48	3 / 47	3 / 46	4 / 45
75	2 / 72	3 / 70	4 / 68	5 / 66	6 / 63
100	2 / 96	4 / 91	5 / 88	6 / 84	7 / 80
125	2 / 118	4 / 112	6 / 106	7 / 101	8 / 96
150	3 / 140	5 / 131	7 / 124	8 / 116	9 / 110
175	3 / 162	5 / 150	7 / 140	9 / 131	10 / 123
200	3 / 183	6 / 168	8 / 156	10 / 144	11 / 135
225	4 / 204	7 / 186	9 / 170	11./ 157	12 / 145
250	4 / 224	7 / 202	10 / 184	12 / 169	13 / 156
275	4 / 244	8 / 218	10 / 197	12 / 180	14 / 165
300	5 / 263	8 / 234	11 / 210	13 / 190	15 / 174
325	5 / 282	9 / 249	11 / 222	14 / 200	15 / 182
350	5 / 301	9 / 263	12 / 233	14 / 209	16 / 189
375	6 / 319	10 / 277	12 / 244	15 / 218	16 / 196
400	6 / 337	10 / 291	13 / 255	15 / 226	17 / 203
425	6 / 355	10 / 303	13 / 264	16 / 234	18 / 209
450	7 / 372	11 / 316	14 / 274	16 / 241	18 / 215
475	7 / 389	11 / 328	14 / 283	17 / 248	18 / 220
500	7 / 405	12 / 340	15 / 292	17 / 255	19 / 226
550	8 / 438	12 / 362	16 / 308	18 / 267	20 / 235
600	8 / 469	13 / 383	16 / 323	19 / 279	20 / 244
650	9 / 499	14 / 403	17 / 337	19 / 289	21 / 252
700	9 / 528	14 / 422	18 / 350	20 / 298	22 / 259
750	10 / 556	15 / 439	18 / 362	21 / 307	22 / 266
800	10 / 583	15 / 456	19 / 373	21 / 315	23 / 272
850	10 / 609	16 / 472	19 / 384	22 / 323	23 / 277
900	11 / 634	16 / 487	20 / 394	22 / 330	23 / 282
950	11 / 658	17 / 501	20 / 403	22 / 336	24 / 287
1000	12 / 682	17 / 515	21 / 412	23 / 342	24 / 292
1100	12 / 727	18 / 540	21 / 428	24 / 353	25 / 299
1200	13 / 769	19 / 563	22 / 442	24 / 363	25 / 306
1300	14 / 809	20 / 584	23 / 455	25 / 371	26 / 313
1400	14 / 847	20 / 604	23 / 467	25 / 379	26 / 318
1500	15 / 883	21 / 622	24 / 477	26 / 386	27 / 323
1600	16 / 916	21 / 638	24 / 487	26 / 392	27 / 327
1700	16 / 948	22 / 653	25 / 496	26 / 398	27 / 331
1800	17 / 979	22 / 668	25 / 504	27 / 403	28 / 335
1900	17 / 1007	23 / 681	26 / 512	27 / 408	28 / 338
2000	17 / 1035	23 / 693	26 / 519	27 / 413	28 / 341
2500	19 / 1154	25 / 745	27 / 547	29 / 430	29 / 353
3000	21 / 1250	26 / 784	28 / 568	29 / 443	30 / 362
3500	22 / 1330	27 / 814	29 / 584	30 / 453	30 / 368
4000	23 / 1396	28 / 839	30 / 596	30 / 460	31 / 373

APPENDIX D

RSED V3.0 TABLES AND PAYMENT ANALYSIS

This appendix contains inspection tables and deduction adjustments (deltas) for RSED V3.0. That is followed by a sample payment analysis. The material within this appendix has been reproduced from preliminary NAVFAC guidance on the proposed method [Ref. 19]. Interesting features are the enhanced inspection requirements and narrowly defined population ranges. There is no CND because extrapolation takes place in the event of any defect.

RSED V3.0 - Table of Sample Sizes
For Normal Sampling Levels

07-07-1986

Sample sizes are for the indicated monthly population:

Population range		Sample Size	Population range		Sample Size
33 -	34	30	35 -	36	31
37 -	37	32	38 -	38	33
39 -	40	34	41 -	41	35
42 -	43	36	44 -	44	37
45 -	46	38	47 -	47	39
48 -	49	40	50 -	50	41
51 -	52	42	53 -	53	43
54 -	55	44	56 -	56	45
57 -	58	46	59 -	60	47
61 -	61	48	62 -	63	49
64 -	65	50	66 -	66	51
67 -	68	52	69 -	70	53
71 -	71	54	72 -	73	55
74 -	75	56	76 -	77	57
78 -	79	58	80 -	81	59
82 -	83	60	84 -	84	61
85 -	86	62	87 -	88	63
89 -	90	64	91 -	92	65
93 -	95	66	96 -	97	67
98 -	99	68	100 -	101	69
102 -	103	70	104 -	105	71
106 -	107	72	108 -	110	73
111 -	112	74	113 -	114	75
115 -	117	76	118 -	119	77
120 -	122	78	123 -	124	79
125 -	127	80	128 -	129	81
130 -	132	82	133 -	134	83
135 -	137	84	138 -	140	85
141 -	142	86	143 -	145	87
146 -	148	88	149 -	151	89
152 -	154	90	155 -	157	91
158 -	160	92	161 -	163	93
164 -	166	94	167 -	169	95
170 -	172	96	173 -	176	97
177 -	179	98	180 -	182	99
183 -	186	100	187 -	189	101
190 -	193	102	194 -	196	103
197 -	200	104	201 -	204	105
205 -	208	106	209 -	211	107
212 -	215	108	216 -	219	109
220 -	224	110	225 -	228	111
229 -	232	112	233 -	236	113
237 -	241	114	242 -	245	115
246 -	250	116	251 -	255	117
256 -	259	118	260 -	264	119
265 -	269	120	270 -	274	121
275 -	280	122	281 -	285	123

RSED V3.0 - Table of Sample Sizes
For Normal Sampling Levels

07-07-1986

Sample sizes are for the indicated monthly population:

Population range		Sample Size	Population range		Sample Size
286 -	290	124	291 -	296	125
297 -	302	126	303 -	308	127
309 -	313	128	314 -	320	129
321 -	326	130	327 -	332	131
333 -	339	132	340 -	345	133
346 -	352	134	353 -	359	135
360 -	366	136	367 -	374	137
375 -	381	138	382 -	389	139
390 -	397	140	398 -	405	141
406 -	414	142	415 -	422	143
423 -	431	144	432 -	440	145
441 -	450	146	451 -	459	147
460 -	469	148	470 -	479	149
480 -	490	150	491 -	501	151
502 -	512	152	513 -	523	153
524 -	535	154	536 -	548	155
549 -	560	156	561 -	574	157
575 -	587	158	588 -	601	159
602 -	616	160	617 -	631	161
632 -	647	162	648 -	663	163
664 -	680	164	681 -	697	165
698 -	716	166	717 -	735	167
736 -	754	168	755 -	775	169
776 -	796	170	797 -	819	171
820 -	842	172	843 -	867	173
868 -	893	174	894 -	920	175
921 -	948	176	949 -	978	177
979 -	1009	178	1010 -	1042	179
1043 -	1077	180	1078 -	1114	181
1115 -	1153	182	1154 -	1194	183
1195 -	1238	184	1239 -	1285	185
1286 -	1335	186	1336 -	1388	187
1389 -	1445	188	1446 -	1507	189
1508 -	1573	190	1574 -	1644	191
1645 -	1721	192	1722 -	1805	193
1806 -	1896	194	1897 -	1997	195
1998 -	2107	196	2108 -	2228	197
2229 -	2363	198	2364 -	2514	199
2515 -	2684	200	2685 -	2876	201
2877 -	3095	202	3096 -	3348	203
3349 -	3643	204	3644 -	3990	205
3991 -	4407	206	4408 -	4915	207
4916 -	5549	208	5550 -	6361	209
6362 -	7439	210	7440 -	8940	211
8941 -	11173	212	11174 -	14847	213
14848 -	22020	214	22021 -	42231	215
42232 -	466033	216	465914 and above use		217

RSED V3.0 - Table of Adjustment Factors

07-07-1986

FOR DEFECT RATE OVER % - THRU %	ADJUSTMENT FACTOR %	FOR DEFECT RATE OVER % - THRU %	ADJUSTMENT FACTOR %
UP TO - 1.0	0.46	1.0 - 2.0	0.64
2.0 - 3.0	0.78	3.0 - 4.0	0.90
4.0 - 5.0	1.00	5.0 - 6.0	1.09
6.0 - 7.0	1.17	7.0 - 8.0	1.24
8.0 - 9.0	1.31	9.0 - 10.0	1.38
10.0 - 11.0	1.44	11.0 - 12.0	1.49
12.0 - 13.0	1.54	13.0 - 14.0	1.59
14.0 - 15.0	1.64	15.0 - 16.0	1.68
16.0 - 17.0	1.72	17.0 - 18.0	1.76
18.0 - 19.0	1.80	19.0 - 20.0	1.84
20.0 - 21.0	1.87	21.0 - 22.0	1.90
22.0 - 23.0	1.93	23.0 - 24.0	1.96
24.0 - 25.0	1.99	25.0 - 26.0	2.01
26.0 - 27.0	2.04	27.0 - 28.0	2.06
28.0 - 29.0	2.08	29.0 - 30.0	2.10
30.0 - 31.0	2.12	31.0 - 32.0	2.14
32.0 - 33.0	2.16	33.0 - 34.0	2.17
34.0 - 35.0	2.19	35.0 - 36.0	2.20
36.0 - 37.0	2.22	37.0 - 38.0	2.23
38.0 - 39.0	2.24	39.0 - 40.0	2.25
40.0 - 41.0	2.26	41.0 - 42.0	2.26
42.0 - 43.0	2.27	43.0 - 44.0	2.28
44.0 - 45.0	2.28	45.0 - 46.0	2.29
46.0 - 47.0	2.29	47.0 - 48.0	2.29
48.0 - 49.0	2.29	49.0 - 50.0	2.29

WHERE SOME DEFICIENCIES ARE NOT REWORKED WITHIN ALLOTTED TIME

a.	Price for specified services	$5,000.00
b.	Population of services this period being billed	1,000
c.	Price per service	$ 5.00
d.	Number of services sampled	100
e.	Number of sampled services rejected	5
f.	Observed defect (reject) rate [(e/d)x100]	5.00%
g.	Adjustment factor Note 1	1.00%
h.	Deductible defect rate (f - g) Note 2	4.00%
i.	Extrapolated defects [Whole number portion of (h x b)/100]	40
j.	Defects observed outside the sample Note 3	23
k.	Acceptable rework completed	3
l.	Net number of services to deduct (i - k) Note 2	37
m.	Deduct for unsatisfactory services (c x l)	$ 185.00
n.	Liquidated damages (10% of c x k) Note 4	$ 1.50
o.	Other adjustments (- for deduct) Note 5	$ 0.00
p.	Total Payment (a - m - n ± o)	$4,813.50

Notes:

1. Adjustment factor varies with observed defect rate.

2. Cannot be less than zero (0)

3. Defects observed outside the sample will not be used as a basis for extrapolation but shall be considered in calculation of payment for satisfactory rework.

4. Liquidated damages calculated as appropriate in accordance with contract provisions.

5. This could include a deduction for work performed by Government or other forces or payment for rework from a prior billing period provided it would not have resulted in less than zero Net Services to deduct (item l above) in that period.

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